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TRANSPORTATION CONTROL STRATEGY DEVELOPMENT FOR THE GREATER HOUSTON AREA

TRW Transportation and Environmental Operations

Prepared for:

Environmental Protection Agency

December 1972

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U.S. ENVIRONMENTAL PROTECTION AGENCY
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The document demonstrates the nature of the Air Quality problem attributed to motor vehicle operation, the magnitude of the problem and a strategy developed to neutralize these effects in order that National Ambient air quality standard may be attained and maintained.

17. Key Words and Document Analysis. 17a. Descriptors

Motor Vehicle emitted pollutants - air pollutants originating within a motor vehicle and released to the atmosphere.

National Ambient Air Quality Standards - Air Quality Standards promulgated by the Environmental Protection Agency and published as a Federal Regulation in the Federal Register.

17b. Identifiers/Open-Ended Terms

VMT - Vehicle Miles Traveled
Vehicle Mix - distribution of motor vehicle population by age group.
LDV - light duty vehicle - less than 6500 lbs.
HDV - heavy duty vehicle - greater than 6500 lbs.

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Office of Air and Water Programs
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December 1972

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1. SUMMARY

This report presents control measures that, if fully implemented, will allow achievement of ambient air quality standards in the Greater Houston Area by 1977. The study was directed toward measures to control "Set II" pollutants, specifically photochemical oxidants and carbon monoxide. There is no identified carbon monoxide problem in the Greater Houston Area. An ozone measurement study was performed on the upper Texas Gulf coast between April and June of 1972. This study identified a regional photochemical oxidant problem of major magnitude. As a result of this study, the baseline maximum one-hour oxidant concentration was revised upward to 0.315 ppm (630 μgm/m^3).

After careful evaluation, a total hydrocarbon emission reduction goal of 75% was established to meet photochemical oxidant standards in the Greater Houston Area. Calculations were performed to determine the total hydrocarbon emissions from all sources including motor vehicles, and to estimate the reduction possible with present stationary source regulations and Federal motor vehicle emission controls. This initial evaluation determined that the ambient air quality standards could not be met by 1977, even with zero mobile emissions, unless hydrocarbon emissions from stationary sources are also reduced significantly.

Stationary Sources

Based on these findings, the Texas Air Pollution Control Board Staff reviewed their inventory of hydrocarbon sources in this region, and reevaluated the reductions that might be realized by imposing the present regulations and additional proposed restrictions.(4) This study resulted in a new estimate of hydrocarbon emissions from point sources and a recommendation that Regulation V be tightened significantly. Since it was clear that stationary source as well as mobile measures were required to reduce hydrocarbon emissions enough to meet the photochemical oxidant standards, the results of the above study and further investigations into potential stationary source reduction measures were included in this evaluation. Additional consideration was given mainly to the control of evaporative emissions from gasoline marketing and solvent users; and with regulations to control fugitive emissions from process industries.

Mobile Sources

The potential measures for reducing mobile source emissions fall into three major groups: control individual vehicle emissions, traffic flow improvements, and reduce vehicle use. Control of individual vehicle emissions involves a multifaceted program affecting both old and new vehicles. Federal motor vehicle emission controls and changes in vehicle engine design will reduce emissions from new vehicles. Vehicle inspection/maintenance can significantly reduce emissions by insuring all in-use motor vehicles are in proper working order, particularly the emission control devices. Retrofit programs can reduce emissions from in-use vehicles by the installation of emission control devices or, a special case, conversion to gaseous fuels. The effectiveness and need for retrofit measures is decreased over time as pre-1975 control vehicles are phased out of the population. A public attitude survey taken in the Houston area indicates there is presently strong public support for an inspection/maintenance program, and Houston area residents generally support a retrofit program if it is not too costly. Figure 1-1 summarizes the reduction in total hydrocarbon emissions from motor vehicles through the present Federal motor vehicle controls and various inspection/maintenance and retrofit options.

Traffic flow improvements will potentially reduce emissions by increasing vehicle speeds and reducing their idling times in traffic. These types of measures are not effective in the Greater Houston Area because levels of traffic service and average travel speed are quite high for an urban area this size. The net result of flow improvement programs is likely to be the preservation of the existing level of service under higher future traffic loads rather than an increase in average travel speed. Reduction in emissions with increases in travel speed becomes quite marginal at speeds above 20 MPH, particularly as post-1975 vehicles become a greater percentage of the vehicle fleet (see Figure 1-2).

The most direct way to reduce emissions from motor vehicles is to reduce their use. This general goal can be approached by three types of measures: reduce trip requirements, provide transportation alternatives or establish vehicle restraints. It is generally found that there is no way, except on a voluntary basis, to reduce trip requirements. Since travel requirements cannot be diminished, some form of transportation alternatives must be provided. These can be in the form of public transit or could include schemes to increase individual vehicle utilization , such as car pool incentives. A major transit improvement program for the Greater Houston Area is currently in the final stages of plan definition. This program constitutes an order of magnitude improvement over existing

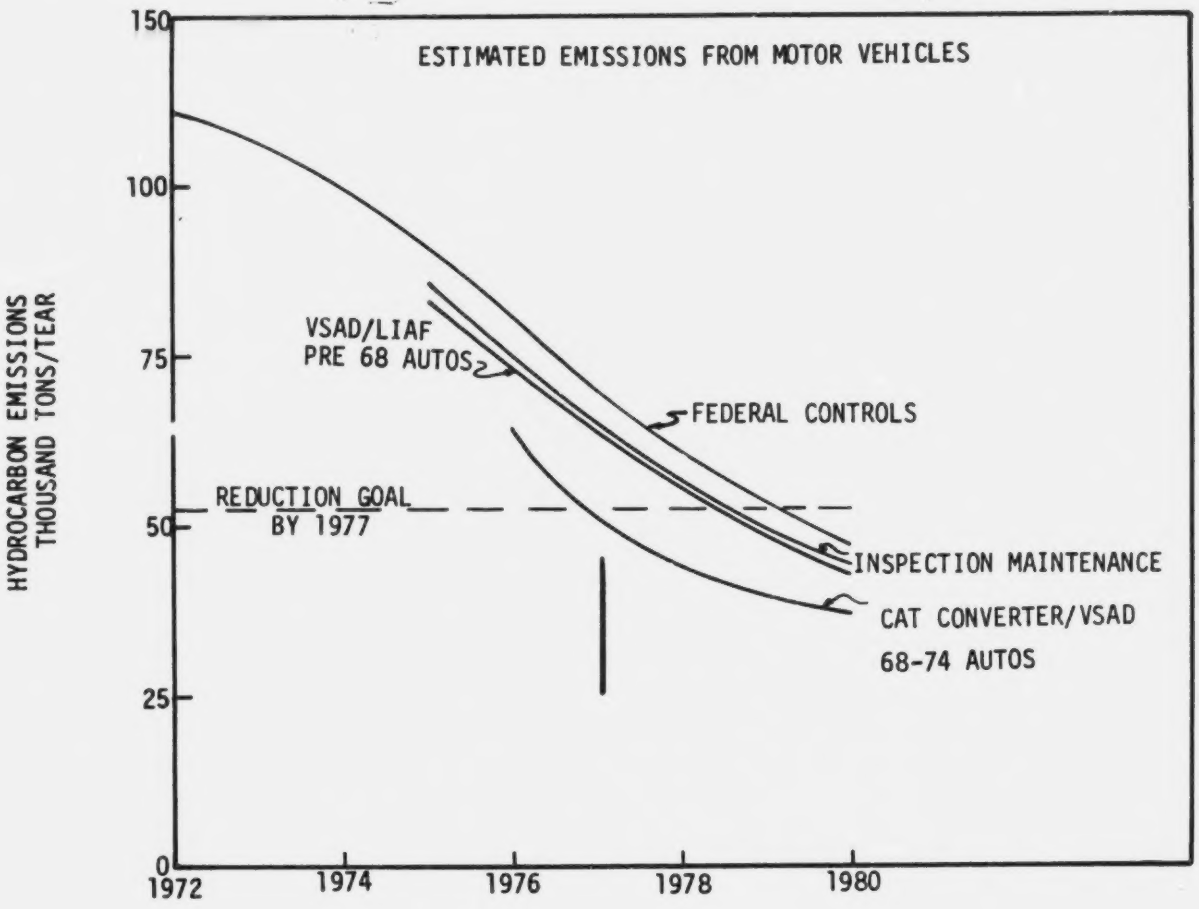

Figure 1-1. Estimated Emissions from Motor Vehicles

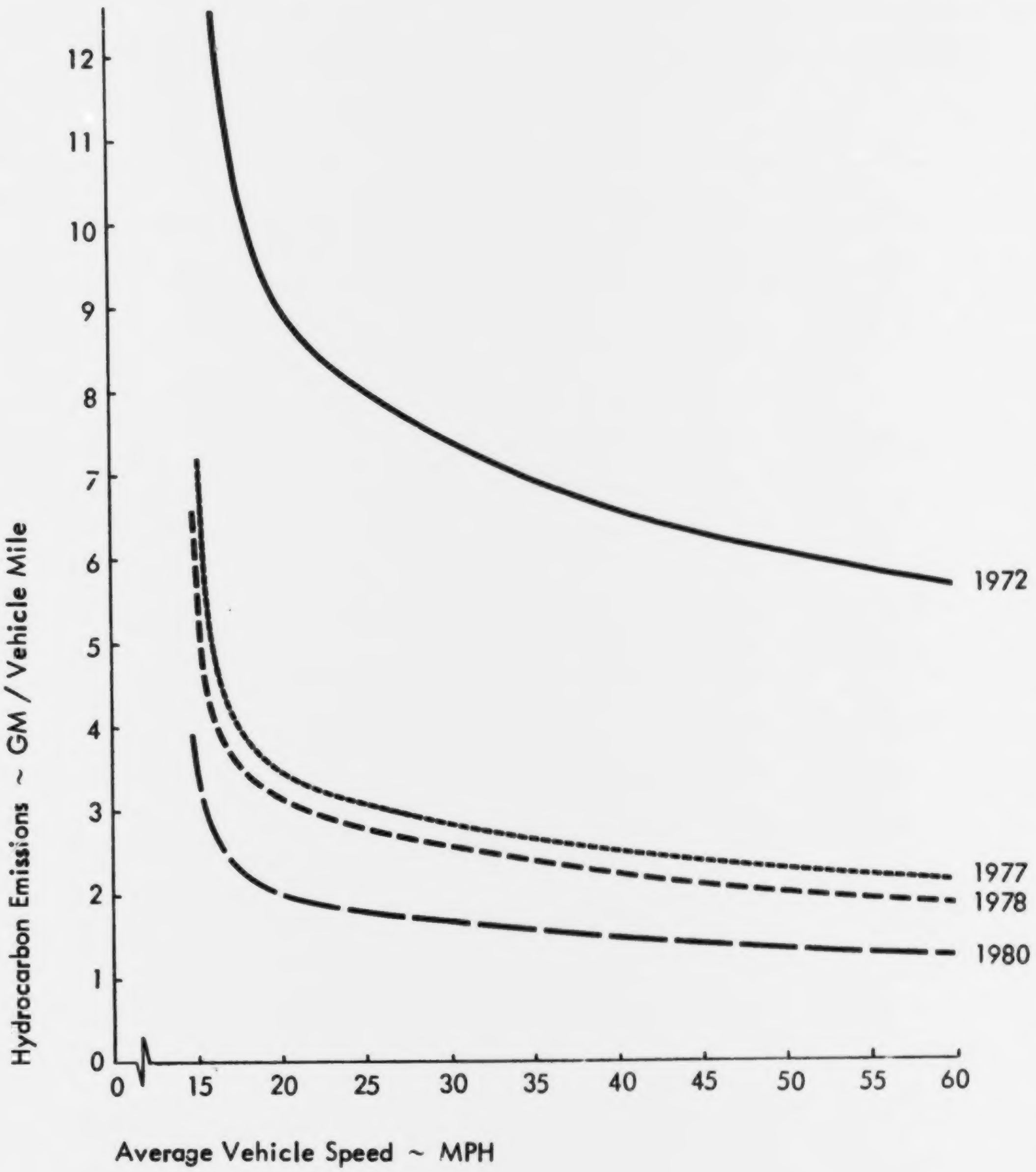

Figure 1-2. Projected Hydrocarbon Emissions Vs. Speed for Light Duty Vehicles with Required Federal Emission Controls

transit service, however, it appears highly doubtful that the first phase of this transit system could be completed by 1977 without immediate commitment and expenditures.

Better efficiency in auto use through shared trip making could significantly reduce VMT, and therefore, emissions. Car pools are an obvious method to increase this efficiency. The public attitude survey conducted in the course of this project indicates that nearly 40% of the respondents are interested in work commute car pooling; however, 70% indicated they would have significant difficulties in joining or organizing car pools. Since one obstacle to car pooling appears to be informational, i.e., making persons with similar trip requirements known to each other, a computer matching service might be particularly helpful. Although this type of program will probably not induce sustantial shifts to car pools, experience in administering an information program will be required in case restrictive driving measures are needed before adequate public transportation is available. Better utilization of the private automobile fleet would be the only transportation alternative available in that situation.

Providing vehicle restraints, the last general category for reducing VMT and the most effective, can be approached by land use controls; or direct regulation of road use, fuel use or auto ownership. Vehicle free zones make a positive contribution to mobile source emission reduction; however, reduction credits resulting from this measure have not been quantified and no specific proposals for vehicle free zones have been developed. Free zones are encouraged wherever they respond to other planning goals and objectives.

Parking control measures have the objective of reducing VMT by inducing car pooling and shifts to public transit. Despite some drawbacks, parking control measures are desirable in the Houston Central Business District (CBD and other activity concentrations which are now or will be served by adequate public transit.

The imposition of tolls on freeways is a method most often put forward for regulating road use. The imposition of tolls on the Houston area freeways is not recommended because the design of the freeways make conventional tolling inefficient. In addition, a high percentage of those priced off the freeways by tolls may drive on surface streets rather than shift to car pools or transit. This could produce increased emissions as a result of reduced travel speed and increased idling on surface streets. Most important, however, tolling measures tend to be regressive. Those priced off the roads will primarily be low income persons.

Tax disincentives are very difficult to access. Schemes to reduce vehicle mileage by gasoline pricing are not very effective. Major increases in price do not appear to affect consumption. People are willing to pay for the convenience of using their cars. Generally, low taxes are ineffective in reducing VMT and high taxes tend to be regressive. The public attitude survey indicates there will be rigorous objections by the public to high taxes.

Even though measures which cost less would not be effective in reducing VMT, they should be given consideration as a means to obtain revenue to subsidize mass transit.

Gasoline rationing is a direct restraint on vehicle mileage and therefore, emissions. Any direct vehicle restraint will be extremely objectionable to the public. However, should one be required, gas rationing appears to be the most effective approach. It can be implemented easier than any other identified direct restriction.

Figure 1-3 presents the percent of vehicle mile travel reduction versus total hydrocarbon emission reductions considering various individual auto control starting points.

Proposed Control Strategy

The proposed strategy is phased so as to take advantage of legislative or judicial remission, technology development and changes in requirements resulting from a better understanding of the air pollution problem in the Greater Houston Area. In its fully implemented form, it will allow air quality standards to be met by the 1977 due date. Phase I measures have substantial justification, either in terms of significant air quality improvement or other urban needs. Present jusitification for Phase II measures is tentative at best. The final decision to implement them must be based on a better demonstration of the need for further hydrocarbon emission reductions than is now available. Figure 1-4 summarizes the emission reductions possible from implementation of Phase I and Phase II of this proposed control strategy.

Phase I Measures

1. Continue evaluation of control measures - Expand the air monitoring program in the Greater Houston Area to include more stations and gas chromotography at selected stations. Initiate a regular review of the air quality and emission inventory data to determine if adjustment of the emission control strategy is required to meet ambient air standards.

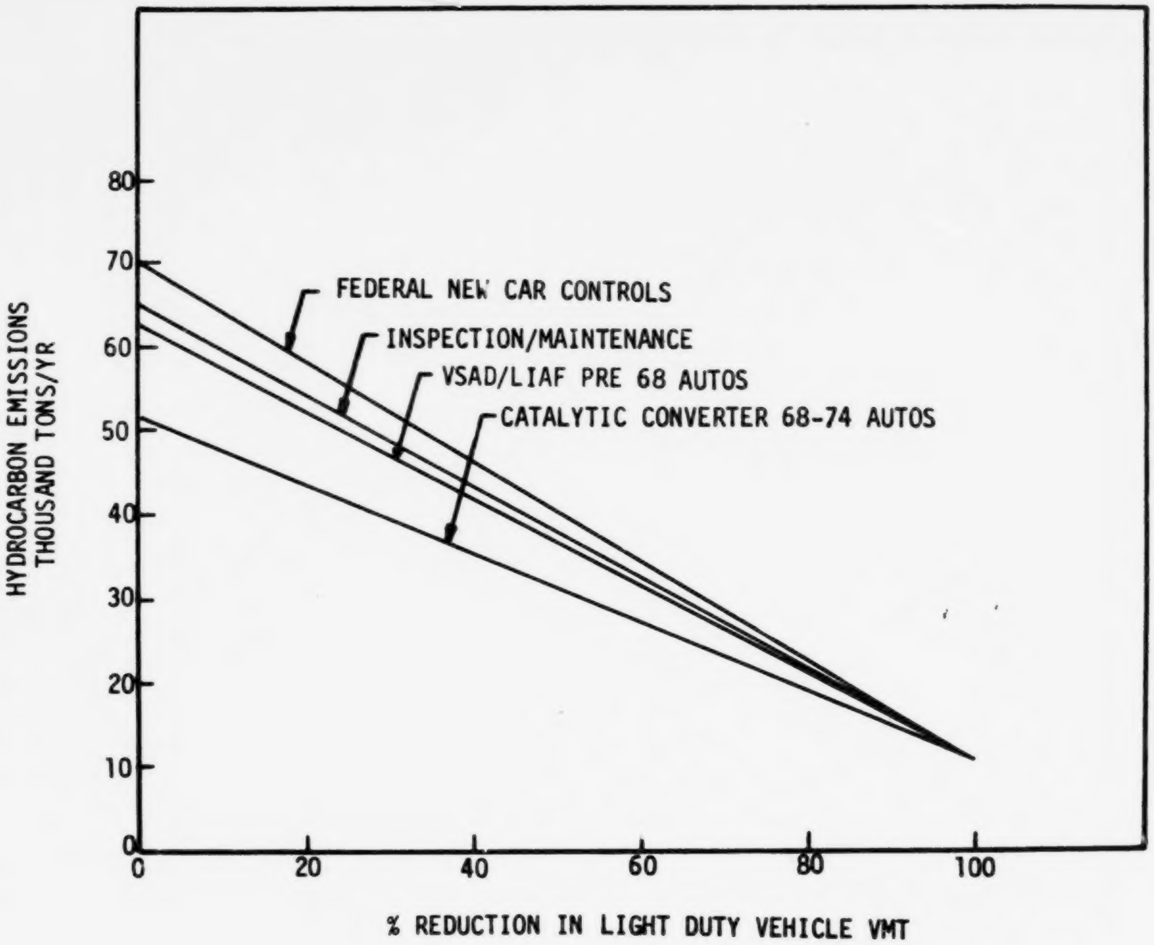

Figure 1-3. Percent Reduction in VMT Vs. Hydrocarbon Emissions

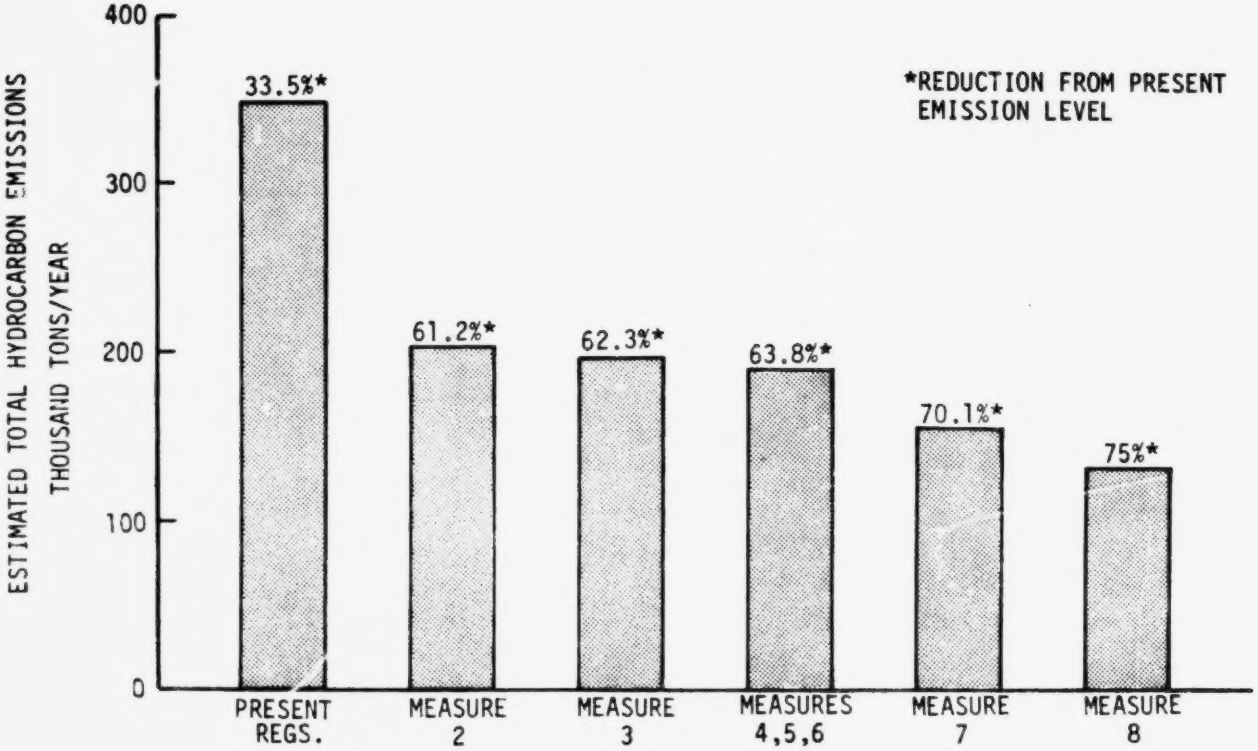

Figure 1-4 Estimated Total Hydrocarbon Emissions in 1977 Resulting from the Proposed Control Measures

2. Stationary source measures - Tighten and expand the Regulation V stationary source controls as recommended by the Texas Air Pollution Control Service's study. Broaden the coverage of Regulation V to include all counties in the region.

3. Mandatory inspection/maintenance - Implement an annual inspection/ maintenance program for in-use vehicles. An idle emission test performed in conjunction with the annual safety inspection is the method recommended.

4. Mass transit - A substantial improvement in mass transit is required in the Greater Houston Area. Based on this need and recognizing the extensive studies that have been performed, it is recommended that Phase I of the Houston Transit Action Program be implemented as soon as possible.

5. Parking measures - It is recommended that parking measures be instituted in all high density areas. These include strict enforcement of existing parking regulations, elimination of preferential rates for all day parking, and establishment of procedures to control parking availability as adequate mass transit is provided.

6. Car pool incentives - Initiate a formal information program with the aim of increasing the amount of voluntary car pooling. This program should include a computer matching element.

It is estimated that measures 4, 5 and 6 will bring about a 3 to 5 percent reduction in VMT. The resulting decrease in emissions are shown in Figures 1-3 and 1-4.

7. Fugitive and evaporative emission controls - (a) Promulgate regulations to control evaporative hydrocarbon emissions from all gasoline marketing levels. (b) Promulgate regulations to control all reactive hydrocarbon emissions from solvent users. (c) Promulgate regulations to attack fugitive losses from all process industries.

Phase II Measures

If at the end of the evaluation period in 1974 it is determined that additional hydrocarbon emission reductions are required, those reductions can be obtained through implementation of the following measure:

8. Motor vehicle emission reduction - (a) Retrofit a catalytic converter on all 1968-1974 automobiles and reduce the vehicle miles traveled during the summer and fall months by 30% or (b) no major vehicle retrofit program and reduce vehicle miles traveled by 50% during the summer and fall months. The method recommended to effect the vehicle mile reduction is gasoline rationing.

As is obvious, implementation of the Phase II measure would be very difficult. Rigorous objections at all levels of government, industry and the public can be expected. For that reason, it is not recommended unless and until the need for additional (over Phase I) hydrocarbon emission reductions are substantiated by additional ambient air quality monitoring.

1.1 LIMITATIONS OF THE TRANSPORTATION CONTROL STRATEGY ANALYSIS

To be acceptable, an air pollution control strategy must reduce emission levels consistant with the attainment and maintenance of National Ambient Air Quality standards. Additionally, an implementable transportation control strategy must consider the economic factors associated with its adoption as well as the social and political changes necessary to accommodate each specific control measure. The air quality benefits must be balanced against the social and economic dislocation cost by its implementation. Limitations in the data and analytical methods became obvious during the course of the study, and care must be taken in the interpretation and evaluation of the control strategy recommendations. The proposed control strategy must be considered as an initial attempt to quantify the relationship between transportation processes and the regional air pollution problem. Further study is indicated and should be used to modify this baseline effort. Several specific areas which need to be confirmed and validated by future study are listed below.

Air Quality Monitoring - The air quality monitoring network in this area is in its infancy. Substantial expansions are required to obtain data good enough to base decisions upon. The trend of ambient measurements during the period before the target year of 1977 must be carefully watched and used to adjust control measures according to observed conditions. Further, specific high measurements obviously due to adverse meteorological conditions may be considered as episode control situations and should not require the imposition of long term transportation control strategies for their solution.

Emission Factors - The mobile source emission estimates in this study are based upon the best available emission factors. These emission factors are being revised in light of in-use and new vehicle testing programs being conducted by the Environmental Protection Agency. It is highly recommended that new emission factors be utilized as they become available to recompute the severity of the mobile source generated emission in the region.

Preliminary data indicates that emissions generated during the first few minutes of vehicle operation represent a large portion of the total emissions during any individual vehicle trip. This implies the reduction in the total vehicle trips may be more important than reducing the vehicle miles traveled. Unfortunately, the data relating to this phenomenon were not sufficiently developed to be used in this study.

Traffic Data Projections - Historically, traffic data projections have not been collected with the view of estimating motor vehicle emissions. The data, including vehicle flow speeds and modal mixes, were reworked into the format necessary for emission calculations. Potential inaccuracies were introduced by this process. Further, projections in vehicle growth have been prepared by various agencies and little unanimity has been found concerning appropriate growth rates. Changes in traffic as well as ambient air quality should be closely monitored between now and 1977 so that deviations can be determined and appropriate adjustments made in the control strategy. It should be noted that stationary source estimates also suffer from inaccuracies in the projection of industrial growth and in quantifying expected results from the application of as yet untested control technologies.

Analytical Technique - The key calculation in control measure assessment is relating emission levels to expected ambient air quality. Due to time and contractual constraints, it was not possible to utilize sophisticated modeling techniques to develop this relationship. Therefore, control strategy reductions were based on a rollback technique that relates existing emissions and air quality on a proportional basis. The use of modeling is highly recommended since it can consider the effects of local meteorological and topographical features and describes the geographical extent of the regional air pollution problem. Such procedures, using models now under development, should be performed between now and 1977, and the results used to modify (if required) the control strategy recommended in this document.

1.2 CONCLUSIONS AND RECOMMENDATIONS

Presented below are the major conclusions and recommendations that have emerged as a result of this study.

Conclusions

- Photochemical oxidants and total hydrocarbons are well above the national standards a significant portion of the time in the Houston area.
- Stationary source as well as mobile source reductions are required to allow the ambient standards to be met.
- There is no adequate definition of the actual effect that emission levels have on ambient air quality in the Greater Houston Area. The present air quality measurements and the accuracy of the emission inventory are not sufficient to develop this relationship.
- Significant reductions in hydrocarbon emissions can be obtained by tightening Regulation V.
- Annual inspection/maintenance is necessary to obtain full benefit from Federal motor vehicle emission controls.
- Traffic flow improvements offer only marginal positive contributions to air quality.
- A substantial improvement in mass transit is required in the Greater Houston Area. The Houston Transit Action Program is a major step in the right direction; however, it is questionable whether the key elements can be completed by the 1977 air quality deadline.
- Substantial mobile source emission reductions over those that can be achieved through individual vehicle emission controls can only be obtained by direct reductions in vehicle miles traveled.
- The use of vehicles cannot be significantly restrained without providing some alternate means of transportation.
- Pricing schemes (including taxes) to discourage auto travel are largely ineffective and heavily regressive.
- Gas rationing appears to be the most directly effective and administratively viable means of imposing VMT reductions.

Recommendations

It is recommended that the Phase I control measures be implemented. The measures have substantial justification, either in terms of significant air quality improvement or other urban needs. The final decision regarding implementation of the Phase II measure should be deferred until the need for additional (over Phase I) hydrocarbon emission reductions are substantiated by further ambient air quality monitoring and a review of the air quality standards in light of the cost to achieve them.

2. INTRODUCTION

This report presents the results of a program to evaluate potential control measures that will allow the achievement of air quality standards for oxidants and hydrocarbons in the Houston-Galveston Region by 1977. The measure evaluations include an assessment of their technical effectiveness and institutional/social feasibility. The program was performed by Transportation and Environmental Operations of TRW, Inc., in conjunction with the DeLeuw, Cather and Company organization, a fully owned subsidiary.

Region Description

The Houston-Galveston area is part of air quality control region (AQCR) 7. The region is composed of 13 counties with an area of 12,428 square miles, and is located on the coastal plains in the southeastern part of Texas (see Figure 2-1). The entire land area of the region is very flat with no characteristic geomorphic features. Altitude varies from sea level on the coast to a maximum of 450 feet in Walker County to the north. The region encompasses the San Jacinto coastal basin and is drained by the Trinity, San Jacinto, Colorado and Brazos Rivers and many minor tributaries. The climate is hot and humid. Temperatures range from 44°F (mean minimum) in January to 93°F (mean maximum) in July. Rapid temperature changes are rare. The annual rainfall averages 45 inches and occurs primarily in the spring and fall.

The major natural resources are the fertile soil, abundant oil and natural gas deposits, abundant sea life and excellent access for ocean shipping. The region has experienced a very strong economic growth (it is one of the fastest growing areas in the United States), and a

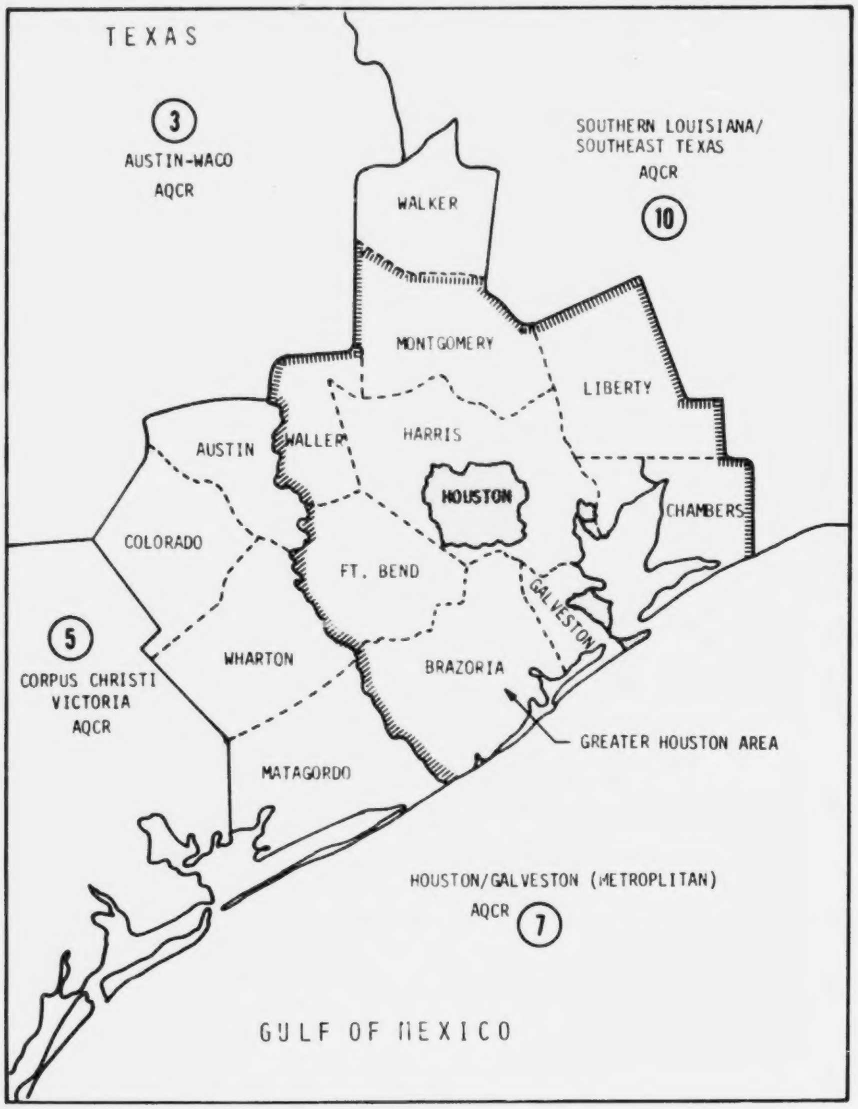
TEXAS
3
AUSTIN-WACO
AQCR
SOUTHERN LOUISIANA/
SOUTHEAST TEXAS
AQCR
10
WALKER
MONTGOMERY
LIBERTY
AUSTIN
WALLER
HARRIS
HOUSTON
CHAMBERS
COLORADO
FT. BEND
GALVESTON
5
CORPUS CHRISTI
VICTORIA
AQCR
WHARTON
BRAZORIA
GREATER HOUSTON AREA
MATAGORDO
HOUSTON/GALVESTON (METROPLITAN)
AQCR
7
GULF OF MEXICO

Figure 2-1. Study Area

continuation of this strong economic growth is anticipated assuming no artifical disincentives are introduced.

According to the 1970 census, AQCR 7 has a population of 2,305,106 people. Houston's population increased 39% during the 1960s which was the fastest rate of growth in any of the nation's ten largest cities. The Greater Houston Area consists of Harris County and the seven counties surrounding it: Brazoria, Chambers, Fort Bend, Galveston, Liberty, Montgomery and Waller counties. The Greater Houston Area population is projected to grow to 5 million people by 1990 and 9 million by 2020. Industrial expansion with its attendant increase in jobs (double by 1990) will cause an increase in industrial and vehicular emission problems unless controlled.

The focus of this study, both in problem evaluation and measure effectiveness assessment, is the Greater Houston Area. Results may not be applicable to either the other counties in the Air Quality Control Region or to the rest of the state.

Problem Definition and Program Description

The Texas Implementation Plan submitted January 28, 1972, classified the Houston area as a class I region for hydrocarbons, photochemical oxidants and nitrogen oxides and a class III region for carbon monoxide. Air quality and emission inventory data can be found in Appendix A. Nitrogen oxide concentrations were slightly over standards and it was estimated that NO_x levels would be within criteria by 1975 as a result of present regulations and measures. In addition, there are potential alterations to the standard methods for measuring nitrogen oxides; therefore, this study did not call for development of strategies to control them. Because the region was classified as priority III for carbon monoxide and since there was no further evidence of localized problem areas, no strategies were investigated specifically for this pollutant either. All efforts were directed to developing strategies that would allow air quality standards for photochemical oxidants and hydrocarbons to be met. There was a basic groundrule that air quality could not be degraded in another area or by a different pollutant as a result of any strategy used to meet criteria.

The Texas Implementation Plan reported the maximum one-hour photochemical oxidant concentration as .15 ppm (300 $\mu gm/m^3$). Based on this measured level, Federal regulations specified a 50% reduction in total hydrocarbons to meet the required photochemical oxidant standard.(1)(2)

A study was performed during April, May and June (1972) to measure ozone by the chemiluminescent method at seven sites along the upper Texas Gulf coast. Four of these sites were in the Greater Houston Area.(3) During this test, ozone concentrations exceeded the national standards a significant portion of the time. Levels in excess of .3 ppm (600 $\mu gm/m^3$) were recorded. A summary of this data can be found in Appendix A. Based on this study the oxidant problem was identified as regional in nature with no indication of local hot spots. In addition, the baseline maximum one-hour oxidant concentration was revised upward to .315 ppm (630 $\mu gm/m^3$). Utilizing this baseline oxidant concentration, the regulations would require a reduction of near 100% of the hydrocarbon emissions to achieve national photochemical oxidant standards. Since this was deemed impractical, EPA authorized use of a formula wherein a direct percentage reduction in hydrocarbon emissions would be assumed to cause an equal percentage reduction in the maximum one-hour photochemical oxidant concentration. Based on this formula, a 75% reduction in total hydrocarbon emissions is required. Since the "degree of total hydrocarbon emission reduction necessary for attainment and maintenance of the national standard for photochemical oxidants will also be adequate for attainment of the national standard for hydrocarbons,"(2) no further reductions are required.

The program purpose then is to develop transportation control strategies (measures) that will reduce total hydrocarbon emissions in the Greater Houston Area by 75%. These strategies must be technically and institutionally feasible, and legal authority to implement the measures must be available or obtainable.

3. CONTROL STRATEGY DEVELOPMENT

A 75% reduction in total hydrocarbon emissions is required in the Greater Houston Area to meet the air quality standards for photochemical oxidants. Before measures to achieve this reduction were evaluated, the decrease in emissions that would automatically result from Federal motor vehicle emission controls, previously programed transportation system improvements, and current stationary source emission regulations was estimated. This estimation defined the magnitude of required additional emission reductions.

3.1 EMISSION ESTIMATES

The estimated hydrocarbon emissions from the major source categories are presented in Figure 3-1. Projections are included for 1975, 77, 78, and 80. These emission estimates are based upon regulations now on the books, including Federal motor vehicle and Texas stationary source controls. The projections in stationary source emissions are based on a 3% increase, but consider that most of the increases will be in new or modified facilities which require application of better technology under the Texas Permits Program. The projections for motor vehicles are based on a 6%/year increase in vehicle miles traveled. These trends conform with recent historical data. A more complete discussion of source emissions and projections can be found in Appendix A. Traffic and vehicle population data used to predict the vehicle contributions can be found in Appendix B. The computer program used to calculate the predicted motor vehicle emissions (and effect on air quality) is described in Appendix G. It is apparent from Figure 3-1 that the required

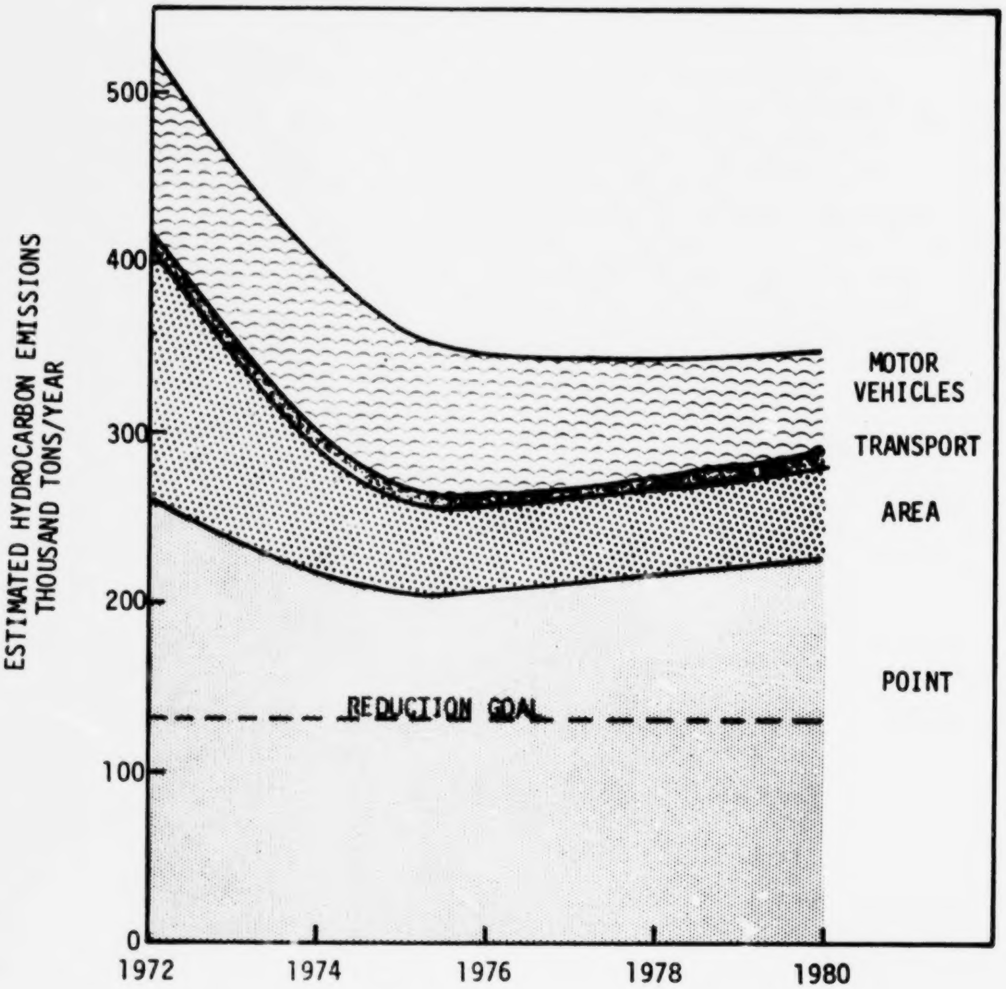

Figure 3-1 Estimated Hydrocarbon Emissions Based on Present Regulations

reduction in hydrocarbon emissions cannot be achieved by only imposing transportation controls. This reduction goal cannot be met even with zero emissions from motor vehicles, unless hydrocarbon emissions from stationary sources are also reduced significantly.

3.2 CONTROL MEASURES CONSIDERED

It is clear that stationary source as well as mobile measures are required to reduce hydrocarbon emissions enough to meet the photochemical oxidant standards. Detail evaluation of stationary source measures fall outside the scope of this study; however, an estimate of the reductions required to meet air quality standards and the effectiveness of control measures available is required.

3.2.1 Stationary Source Measures

As a result of the above findings, the Texas Air Pollution Control Services undertook a study to reevaluate their hydrocarbon emission regulations.(4) This study included a review of all industrial point source categories and resulted in a recommendation that Regulation V be extended to include ethylene released from consuming plants and expanded to include smaller tanks; and all vents not now abated from all of the significant sources in the process industries. Application of this tighter regulation to all counties in the Greater Houston Area results in the reductions shown in Figure 3-2. The improvement is substantial but still not enough to allow the reduction goal to be met by the application of transportation controls.

Area sources are now a significant portion of the total hydrocarbon emissions. Two of the most significant categories of area sources are evaporative losses from gasoline marketing and from certain solvent

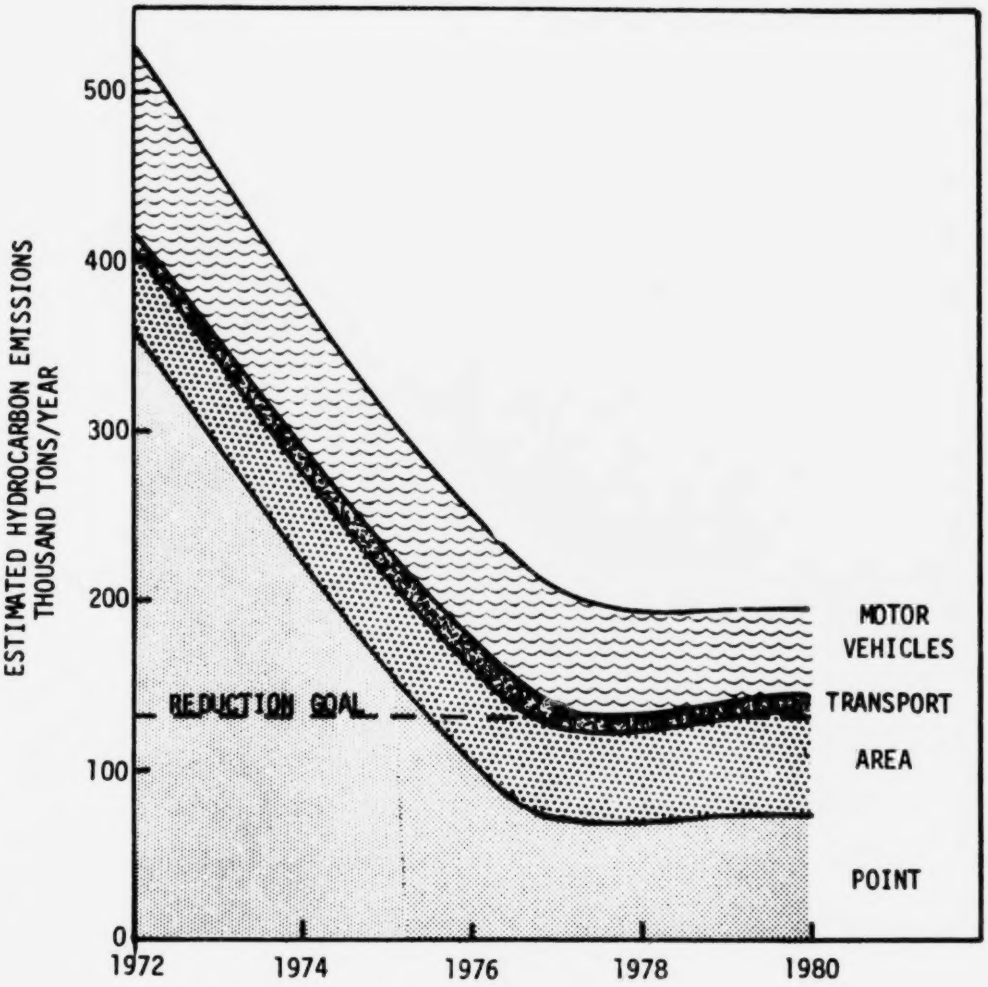

Figure 3-2. Estimated Hydrocarbon Emissions Considering a Tightened Regulation V.

user categories. Several methods are available for controlling evaporative losses from gasoline marketing. These include an adaptive pump nozzle, absorber or condenser system and/or a vapor return and recovery system. Approximately 70% of the vehicles on the road, mostly domestic, can be serviced from one adaptive pump nozzle. The average cost of equipping service stations in the Houston area with evaporative recovery systems would run approximately $2000 per station. Developmental and distributional problems may limit the availability of this type of equipment for the near term. Furthermore, the economic impact of this control approach should be further investigated. Appendix F presents a report on some of the experiences the San Diego Air Pollution Control District have had with implementing an emission regulation that affects gasoline marketing.

Controlling the Reid vapor pressure on a seasonal basis in the Houston area should be considered. THis could yield a significant reduction in evaporative losses with a moderate impact on overall marketing operations. Some drivability problems (during startup) may occur, although they should be of a minimal nature.

Further reductions in hydrocarbon emissions can come through control of organic solvents. Dry cleaners, printers, degreasing operations, etc., could be required to incinerate or absorb evaporative emissions. There are certain organic solvents which have been shown to be virtually unreactive in the formation of oxidants, and still others which have a low reactivity. Substitution of these compounds for high reactive compounds should be encouraged. Emissions from architectural coatings can be reduced by requiring the use of water base or other coatings having an inorganic solvent content of less than 20%.(2)

Implementation of area source regulations of the type described above would result in total hydrocarbon emissions, as shown in Figure 3-3. Figure 3-4 is a comparison of hydrocarbon emissions in the Greater Houston Area in 1977 based on the three levels of stationary source controls described.

Some additional point source reductions could be obtained through the application of a regulation attacking fugitive losses. Fugitive losses are defined as hydrocarbon emissions escaping from pumps, compressors, valves, etc. in process operations. Fugitive losses are the largest single remaining category within the point sources; however, to substantially reduce them would be a major task with an additional 20% reduction the most that could be hoped for.

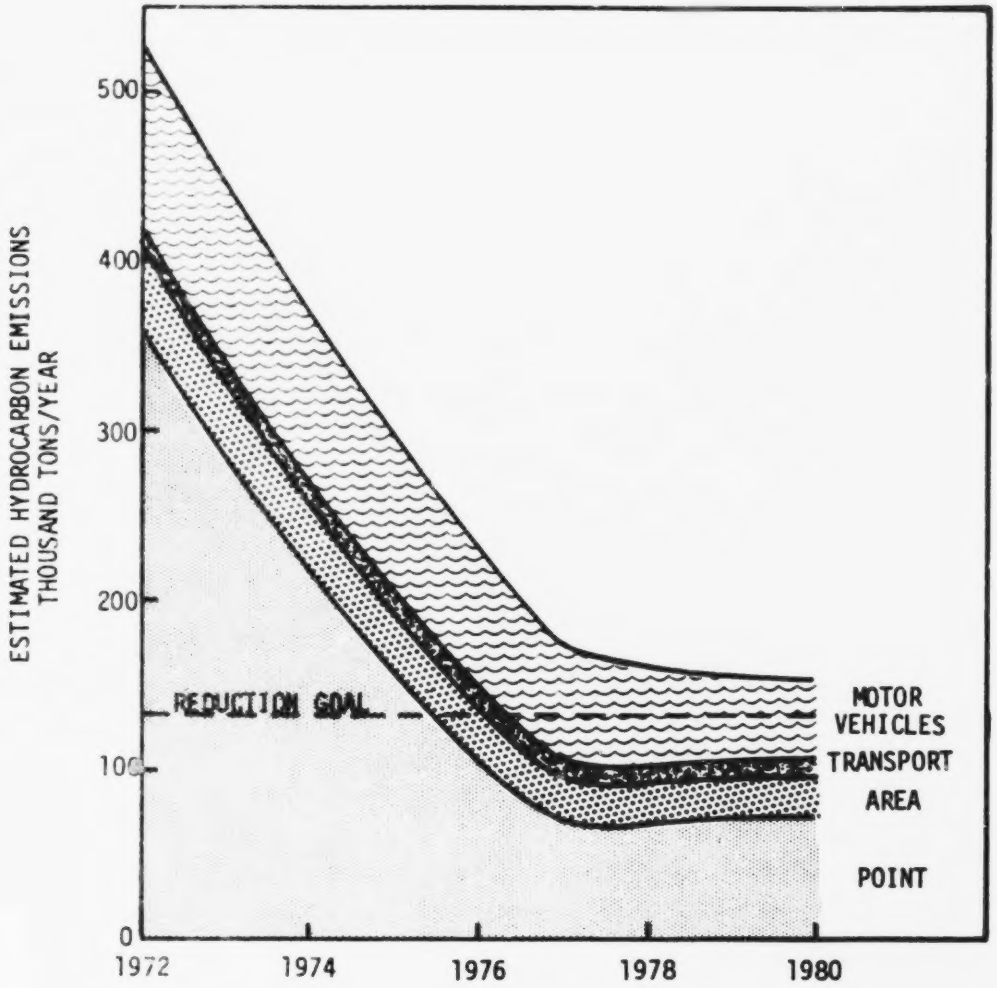

Figure 3-3. Estimated Hydrocarbon Emissions Considering a Tightened Regulation V Plus Evaporative Controls on Area Sources

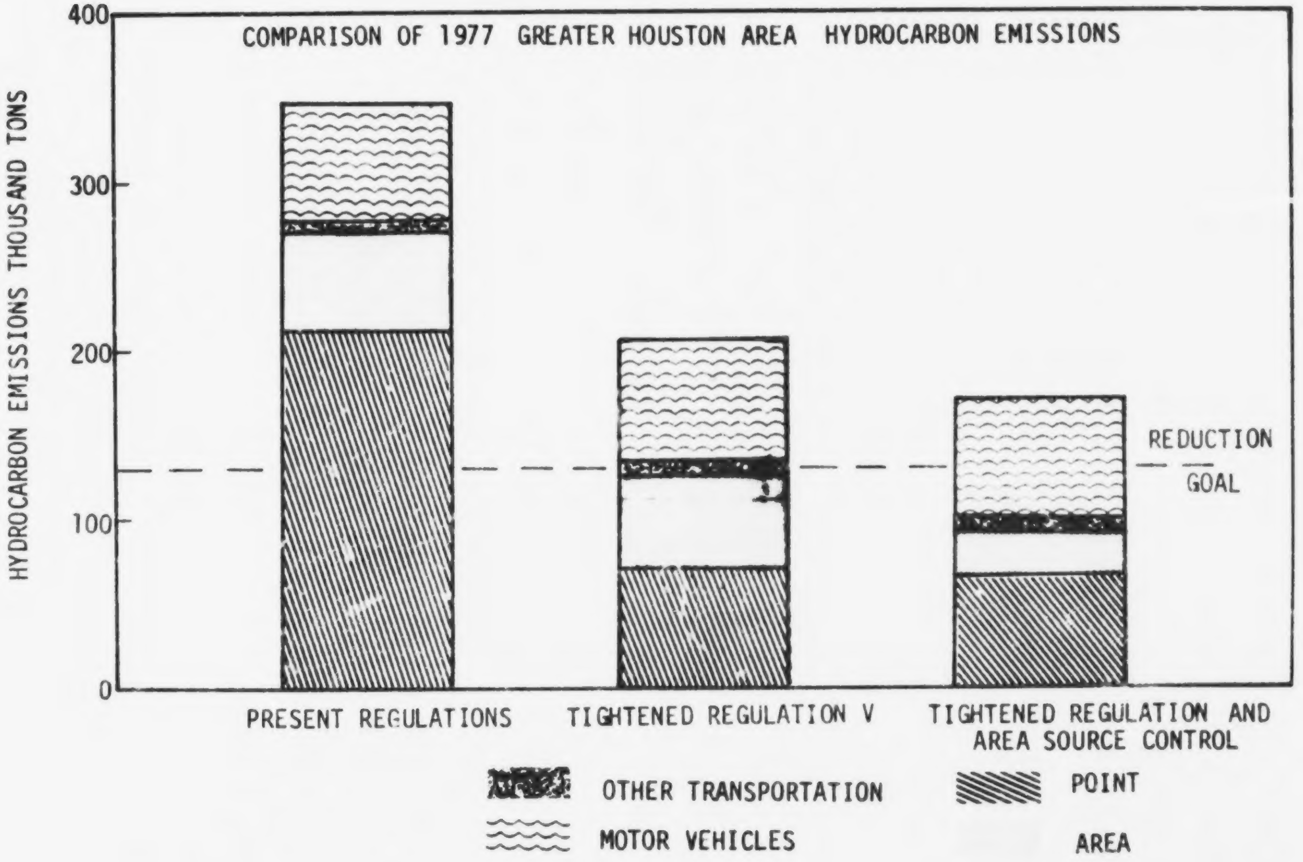

Figure 3-4. Comparison of 1977 Hydrocarbon Emissions Based on Various Levels of Stationary Source Controls

3.2.2 Mobile Measures

A large number of potential measures to reduce mobile source emissions have been identified. Table (3-1) lists the control measures seriously considered for the Greater Houston Area. The measures have been aggregated into groups based on the primary effect they are intended to achieve. The following is a brief discussion of each category with some discussion of subgroupings.

3.2.2.1 Control Individual Vehicle Emissions

Reducing emissions at the source involves a multi-faceted program affecting both old and new vehicles. Federal motor vehicle emission controls and changes in vehicle engine design will reduce emissions from new vehicles. Vehicle manufacturers are the responsible agent, and they pass along the cost of this effort to the car buyer. Vehicle inspection/ maintenance can significantly reduce emissions by ensuring all in-use motor vehicles are in proper working order, particularly their emission control devices. The required programs are administered by the state. The operating costs are passed directly to the user, but start up costs may be subsidized by state or federal agencies utilizing tax revenues. Retrofit programs can reduce emissions from in-use pre-1975 vehicles by installation of emission control devices or (a special case) conversion to CNG or LPG. In this case, the state generally assumes the responsibility for the administration of the necessary programs. The costs are passed on directly to the user or may be subsidized by state agencies utilizing tax revenues. Effectiveness and need for the retrofit measures is decreased over time as pre-1975 control vehicles are phased out of the vehicle population.

Table 3-1 Mobile Source Control Measures

Control Individual Vehicle Emissions

- Inspection/Maintenance
    - Mandatory Maintenance
    - Diagnostic Inspection
    - Emission Inspection
        - Loaded test
        - Idle test
- Retrofit Measures
    - Crankcase
    - Evaporative
    - Exhaust
        - VSAD/LIAF
        - Air bleed/VSAD
        - EGR
        - Catalytic converter
        - Capacitive discharge ignition
- Federal Emission Controls

Traffic Flow Improvements

Operational Improvements
New Facilities
Work Schedule Changes

Reduce Vehicle Use

- Reduce Trip Requirements
    - Work Schedule Changes (4-day week)
    - Other Communications
- Provide Transportation Alternatives
    - Public Transit
    - Car pools
- Provide Vehicle Restraints
    - Vehicle Free Zones
    - Parking Controls
    - Freeway Tolls
    - Restrictive Ramp Metering
    - Moritorium on Traffic Improvements
    - Tax Disincentives
    - Gasoline Rationing

Inspection/Maintenance Measures - Mandatory maintenance, engine diagnostic inspection, and exhaust emission inspection are all approaches to reducing emissions from in-use motor vehicles. All approaches are aimed at ensuring motor vehicles are maintained in a manner sufficient to keep emissions at a minimum.

The emission inspection procedures include the idle-mode-test (where emissions are measured during normal vehicle operations at idle), and various dynamic mode tests (emissions are measured during representative driving conditions which require the use of dynamometers to provide the necessary engine loading). Analysis of data presently available does not indicate any significant difference among the emission reductions achieved as a result of mandatory maintenance, emission inspection, or engine parameter inspection measures for the current light-duty vehicle population. The average initial effectiveness observed is:

- Hydrocarbon exhaust emissions: 20% reduction*
- Carbon monoxide exhaust emissions: 18% reduction*
- Oxides of nitrogen exhaust emissions: no significant change*

These results demonstrate that significant emission reductions can be achieved by the proper servicing of the vehicle population. Estimates for the cost per vehicle for the various inspection/maintenance measures are shown in Table 3-2 .(5) These costs estimates are based on a 12-month inspection interval and a yearly maintenance requirement. If 6-month inspection intervals were implemented, the cost would be approximately twice those shown on the table.

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*Keyword is initial effectiveness. Overall effectiveness must consider normal deterioration in performance until next cycle.

Table 3-2. Yearly Vehicle Owner Costs for Different Inspection/Maintenance Approaches

	Inspection[a] Cost	Maintenance[b] Cost	Total[c] Cost
Mandatory maintenance	$ 0	$ 55	$ 55
Diagnostic inspection	7	25	32
Emission inspection	2	25	27

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[a] Ammortized initial capital investment plus yearly operating costs.

[b] Average cost of maintenace. Assumes all vehicles require yearly maintenance

[c] Inspection plus maintenance cost.

As can be seen from the table, the emission inspection approach appears to be the least cost method of providing incentives for proper maintenance. Emission inspection also appears to be the superior method because of simple enforcement and flexibility for meeting changing requirements. Enforcement is simplified by requiring only that the vehicle meet a specific emission limit to be certified. This provides a direct measure of the desired effect, the limits of which can be adjusted as required to meet clean air goals (on a yearly basis if need be). Enforcement of mandatory maintenance and diagnostic inspection would require very rigid rules and regulations to be placed on the adjustments and service allowed on individual autos. The emission test leaves the method of achieving emissions goals up to the individual car owner (he may opt for an additional control device to allow tuning for performance rather than emissions). This feature should make emission testing more acceptable to the public than the other methods.

A Public Attitudes Survey taken in the Houston area indicates there presently is strong public support for an inspection/maintenance program (see Appendix E). Some 82% of the respondents are in favor and another 10% indicate they are not strongly opposed to such a program. The respondents indentified a charge of nearly $5.50 as a reasonable cost for the annual inspection, significantly above the actual estimated cost in the program under consideration. Some 42% of the respondents felt that the inspection should be done at state operated centers. Nearly 46% favored private garages and service stations and less than 10% favored city operated stations.

Emphasis has been placed by the Federal government on the correlation of any emission inspection procedure to the full Federal test procedure.(6) Dynamic mode emission tests (which require the use of the dynamometer) provide the best correlation. Loaded constant speed tests using tailpipe concentration measurements achieve a satisfactory level of correlation (a dynamometer is still required to load the engine). Idle mode concentration tests have, as yet, not been adequate in this regard. Correlation to the Federal test procedure is important only for the following reasons. (1) The government believes that unless the inspection program correlates with the Federal test procedure there may be no assurance that the use of the inspection as a basis for requiring maintenance provides any real contribution to the improvement of air quality. In the absence of such confidence the state might not be eligible for Federal financial support of the inspection program as authorized by Section 210 of the Clean Air Act. (2) The government believes that an acceptable level of correlation must be achieved to satisfy the enforcement requirements for the warranty provisions included in Section 207B of the Clean Air Act. If implemented, the warranty would require manufacturers to bear the cost of any maintenance necessary to bring vehicles into compliance within the framework of an in-use vehicle inspection test, if such vehicles have been properly operated and maintained. Extensive tests by independent groups such as the Arco Clean Air Caravan have shown that substantial emission reductions can be claimed for maintenance performed as a result of idle emission test results alone.(7)(8)(9) The idle test is not as yet able to provide the diagnostic capability of the loaded emission test. Diagnostic capability is the main advantage to the Federal test procedures and loaded emission test. The idle emission test can, however, identify poor performance and that maintenance is required. The resulting maintenance provides emission reductions - not the inspection.

Retrofit Measures - Retrofit is defined as an application of any device or system that may be added to a motor vehicle, and/or any modification or adjustment beyond that of regular maintenance which could be made to reduce vehicular emissions. There are three primary emission sources in motor vehicles which can be potentially controlled by various retrofit procedures. For vehicles without emission controls, crankcase venting typically contributes about 20% of the total hydrocarbon emission from the vehicle. Another 20% of the total hydrocarbon emission typically result from evaporative losses from the carburator and the fuel tank system. Exhaust emissions account for the remaining 60% of the hydrocarbon emissions, and 100% of the carbon monoxide and nitrogen oxide emissions from uncontrolled vehicles. In the Greater Houston Area, the only identified pollutant problem is photochemical oxidants which require a reduction in hydrocarbons. Therefore, a retrofit system's ability to reduce hydrocarbons will be its key evaluation paramete..

Crankcase emissions systems have been installed on automobiles for some time, therefore crankcase emission retrofit devices will not be considered. Evaporative emission control systems are more recent on new cars; however, there are no available retrofit systems for this emission category. For this reason, retrofit devices to control evaporative emissions will not be considered either. Should a device become available, substantial reductions in hydrocarbons emissions could be achieved through its application. Many exhaust emission control retrofit kits have been evaluated and the results are summarized in an EPA report titled "Control Strategies for In-Use Vehicles."(5) The more successful retrofit options were sited in a draft revision to the implementation regulations,(6) and are listed in Table 3-3 with their average pollutant reduction per vehicle and typical installed cost.

Although there are many potential retrofit options, the measures listed in Table 3-3 are generally conceded to be the most cost effective in their individual categories.(5)(6)(10)(11) As stated earlier, hydrocarbon reduction efficiency is the key evaluation parameter for retrofit systems in the Houston area. Therefore, the exhaust gas recirculation and air bleed retrofits can be eliminated. This is because they are less effective in controlling hydrocarbon emissions and cost considerably more than the VSAD/LIAF retrofit device.

Table 3-3 Effectiveness of Alternate Retrofit Devices

Retrofit Option	Installed Cost	Average Reduction per Vehicle HC	CO	NO_x
Pre-controlled Vehicles				
Lean Idle Air/Fuel Ratio Adjustment and Vacuum Spark Advance Disconnect	$ 20	25%	9%	23%
Oxidizing Catalytic Converter and Vacuum Spark Advance Disconnect	195	68%	63%	48%
Air Bleed to Intake Manifold	60	21%	58%	0%
Exhaust Gas Recirculation and Vacuum Spark Advance Disconnect	110	12%	31%	48%
Controlled Vehicles				
Oxidizing Catalytic Converter	$175	50%	50%	0%
Exhaust Gas Recirculation	90	0%	0%	40%

The vacuum spark advance disconnect (VSAD) is a retrofit device which can be installed in all used cars up to and including 1970. It disconnects the vacuum spark advance except when a thermostat switch senses the car is tending to overheat In that case, the advance is reconnected until the engine cools down. The lean idle air fuel adjustment (LIAF) requires tuning for a low idle engine rpm with a high air to fuel ratio, normally 14 to 1. A single measure made of the two combined retrofit approaches is very cost effective and results in significant reductions in both hydrocarbons and nitrogen oxides for affected vehicles. This option is very easy to implement, however, it must be accompanied by a means to protect against engine overheating, particularly with older cars of marginal cooling capacity. Part throttle economy and performance is degraded slightly and may be the source of some complaints from the public.

The oxidizing catalytic converter is highly efficient in the reduction of hydrocarbon and carbon monoxide emissions. On older cars it would require detuning to allow the car to run on lead free gasoline and should include the vacuum spark advance disconnect retrofit to improve effectiveness with nitrogen oxides. The actual converter is a device installed in the engine exhaust system between the exhaust manifold and the muffler. The converter catalyst can be "poisoned" by leaded fuel although recent prototype tests have shown the catalyst to be somewhat tolerant of lead-containing fuel if it is not used more than 10% of the time.(12)

Houston area residents generally support a retrofit program if the cost is relatively low. In a recent survey, 71% indicated they would favor a retrofit program costing about $50 and another 9% indicated they would not have strong objections to it. (See Appendix E) If the retrofit to pre-1975 vehicles were to cost $200, only some 35% would support it. The inference is that the public feels a retrofit program for pre-1975 vehicles is a reasonable request if it is not too costly.

Gaseous fuel conversion is a special case of vehicle retrofit. Within the near future only three types of gaseous fuels can be seriously considered as alternatives to gasoline for powering motor vehicles: liquified petroleum gas (LPG), compressed natural gas (CNG), and liquified natural gas (LNG). These fuels are inherently clean burning and produce fewer hydrocarbons than gasoline owing to their lower molecular weight and carbon content. Modification to gaseous fuel requires the installation of a special carburetor, special tank (pressure tanks for LPG and CNG, and cryogenic tanks for LNG), pressure regulating devices, shutoff valves and fuel lines. This is generally regarded as a simple conversion although more sophisticated modifications like engine gas recirculation and catalytic converters can also be added for futher reductions. For simple conversion, the cost of modifying an in-use light duty vehicle to CNG or LPG ranges from $350 to $500, while conversion to LNG may cost from $800 to $1000. Large scale mandatory conversion of motor vehicles to gaseous fuels is unwarranted in Houston because the fuel supply and distribution network is very limited. Conversion of large numbers of vehicles and implementation of an adequate fuel distribution system would be extremely expensive. Considerable efforts are underway to meet stringent 1975-76 Federal emission standards through modification of conventional gasoline engines. If successful, these efforts would obviate the need for gaseous fuel systems. (Simple conversion systems would be unable to meet the 1975-76 standards without further engine modifications and supplemental equipment.) Given the substantial initial cost associated with conversion to gaseous fuels, fleet owners could also be expected to resist strongly any governmental attempts to require fleet conversion as a short term air pollution measure. On the other hand, it is appropriate that the conversion of pre-1975 gasoline powered vehicles to gaseous fuels be encouraged by providing tax incentives. With adequate tax incentives and the economics inherent in gaseous fuel operation, large fleet owners may find it to their economic advantage to proceed with the high cost of conversion. All such action should be encouraged.(13)(14)(15)(16)(17)

3.2.2.2 Traffic Flow Improvements

Measures to achieve emission reductions through improved traffic flow fall in two categories: construction of new major traffic facilities (freeways, expressways and major arterial linkages) and operational improvements to existing streets and highways. The emission reductions are brought about by increases in vehicle speeds, reduced idling, and a general shortening of trip times.

Major facility construction normally enables significant increases in vehicle travel speed in the corridors affected but also tends to activate latent travel demand. In the long run this reinforces auto dependence and increases vehicle miles traveled. Over the short range time frame of primary concern in this study (to 1977) the air quality impacts of new traffic facilities can be assumed positive. The most significant major new facility which will come into use in the time period of concern is the East Loop Freeway (I-610). Though its impacts on air quality in that period will be positive, its contribution in terms of regional air quality is too small to quantify.

Operational improvements to existing streets and highways cover a broad range of programs. These include freeway improvements such as ramp metering and removal of bottlenecks; and surface street improvements such as areawide signal system integration, intersection channelizations, minor widenings of streets and intersection approaches, institution of one-way street systems and the like. Because they do not produce dramatic shifts in accessibility, operational improvements generally do not lead to activation of latent travel demand and their impact on emissions and air quality over the study period is assessed as positive.

A number of traffic operational improvement programs are ongoing in the Greater Houston Area. Freeway ramp metering is already utilized on the Gulf Freeway and produces positive flow improvements. Metering has the added utility of enabling bus priority entry to freeways and could also be used in the future as a vehicle restrictive measure rather than for flow improvement purposes. Other extensive traffic flow improvement programs for surface streets are also ongoing in the various responsible jurisdictions. However, operational and flow improvements do not have a high payoff in terms of vehicle emission reductions for several reasons.

- Levels of traffic service and average travel speed in the Greater Houston area are quite high for an urban area of this size. The net result of flow improvement programs is likely to be preservation of the existing level of service under higher future traffic loads rather than an increase in average travel speed.

- Reductions in emissions with increases in travel speed become quite marginal at speeds above 20 miles per hour, particularly toward 1977 as post-1975 model vehicles become a greater and greater percentage of the vehicle fleet, as indicated on Figure 1-2. Average travel speed is high (above 30 mph) and the percentage of operations in the high leverage area below 20 miles per hour is small. Moreover, of operations in the below 20 mph range, few can be impacted as many occur on local neighborhood streets where higher speeds are undesirable.

Flow improvement measures are seen as positive in terms of effect on air quality but their specific contribution to areawide emission reduction in the Greater Houston Area is small and difficult to quantify. Where potential improvement projects in areas of operation in the high leverage speed range below 20 mph can be identified, they are particularly encouraged as these can have beneficial emission impacts out of dimension with the actual number of operations and VMT affected.

Work Schedule Changes - Changes in work schedule have been proposed as a control measure in some cities as they tend to produce marginal flow improvements by reducing commute period traffic congestion and reducing total work commute travel. Two types of schedule changes have been identified; staggered work hours and the four-day week.

Surveys of employees starting and quitting times in the Houston CBD were conducted by the Houston Chamber of Commerce in 1972(18) and in July 1972 the Texas Highway Department conducted traffic counts in the morning and evening peak periods, accumulating volumes in 5-minute intervals. Findings of these data gathering activities were published in the October 1972 issue of Houston Magazine. The survey indicates that there already is a considerable staggering of quitting times in the Houston CBD. Only 34% of the employees in the CBD quit at 5 P.M. Nearly 27% quit before or at 4:30 P.M. Another 17.5% quit at 4:45. However, relatively few CBD workers have quitting times later than 5 P.M.

In the morning the situation is quite different. Fifty-three percent of the CBD employees start work at 8 A.M. Less than 2% start before 7:30 and less than 5% start between 8:45 and 9:15.

Figures 3-5 and 3-6 show the morning and evening loadings on the radial freeways expressed in percent of capacity plotted against CBD starting times. The freeway loading time scale has been adjusted for the offset of the count points from the CBD (to show the correspondence between peak traffic and shift hours) on the basis of the Houston-Harris County Transportation Study's 1969 Freeway Travel Time Survey.(19)

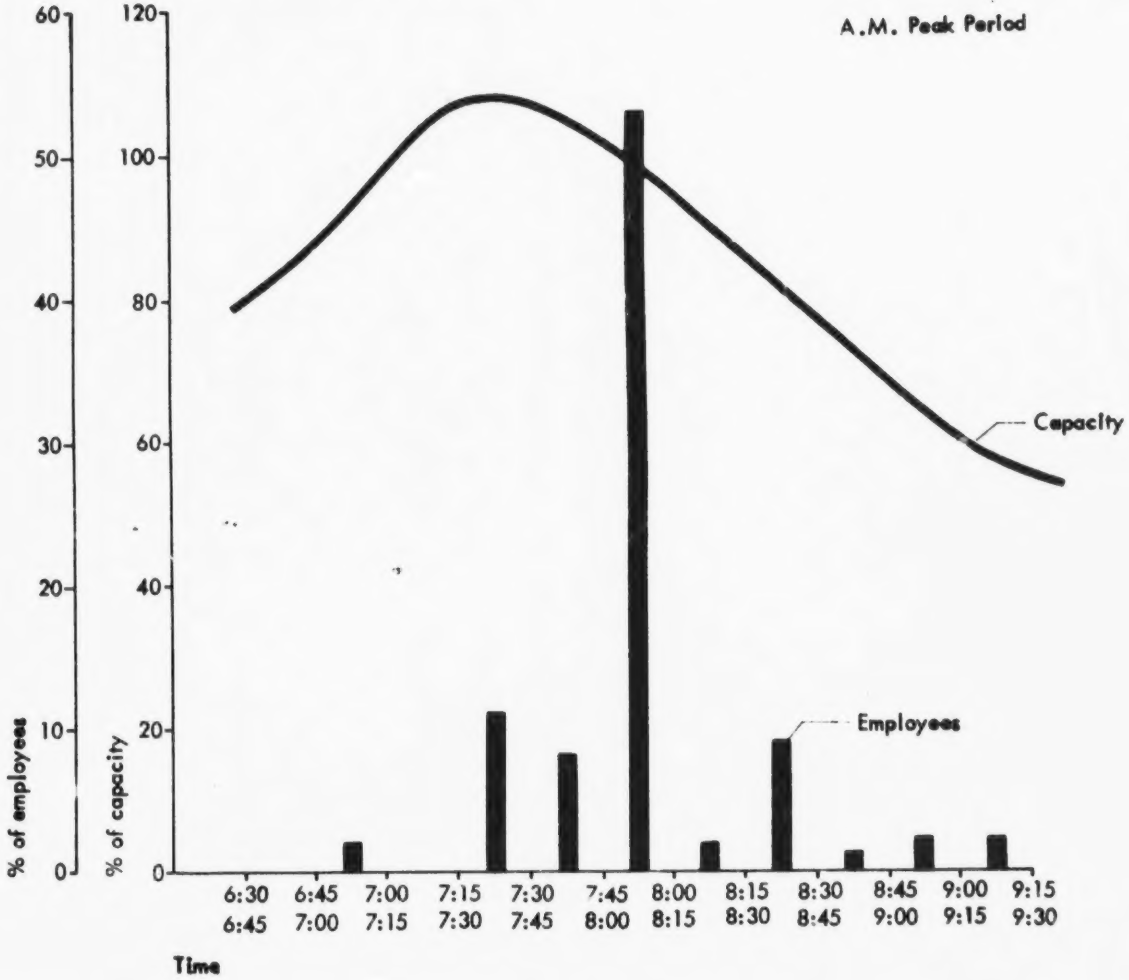

Figure 3-5. Houston CBD Employee Starting Times and Radial Freeway Loadings.

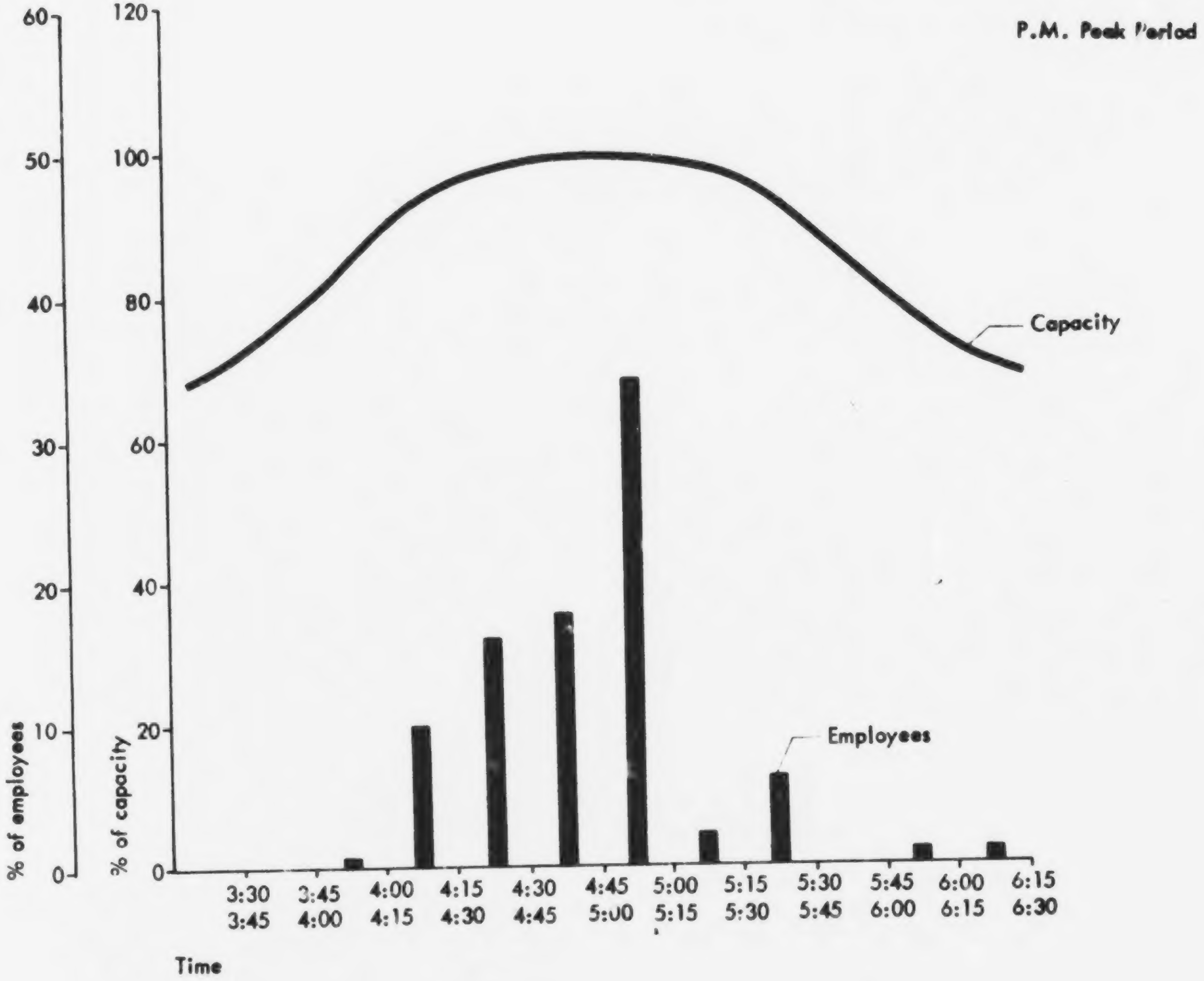

Figure 3-6. Houston CBD Employee Quitting Times and Radial Freeway Loadings

Although the freeways show high levels of utilization, comparison of the two figures shows the impact of the substantial staggering in the evening as opposed to the high concentration in the morning peak work trip period.

The implication is that more extensive staggering of work hours could result in some flow improvement. However, as demonstrated previously, flow improvements produce only marginal reductions in emissions.

The air quality problem in this region results from excessive areawide hydrocarbon emissions on an all day basis. Such a problem responds most directly to decreases in total daily areawide VMT. Staggered work hours do not decrease total daily VMT but simply spread the time of VMT generation. Such a strategy is most applicable when the problem is a short duration, localized concentration of pollutant, particularly carbon monoxide, which results from temporal concentration of traffic flow. Staggered work hours also tend to reduce the potential for car pooling, a measure which does relate well to a hydrocarbon problem as it tends to directly reduce VMT. For these reasons, staggered work hours are not recommended as a pollution control measure in the Greater Houston Area.

The four-day week would reduce VMT generated in work commute travel. Like staggered work hours, this would be a useful measure if the problem were a localized, temporal problem in employment concentration areas. However, indications are that increased recreational and other non-work travel will fully replace if not exceed the reductions in VMT resulting from decreased work commuting. Thus, this measure does not respond well to the region's areawide hydrocarbon emission problem and because of this factor as well as problems of institutional feasibility, the four-day week is not recommended as a control measure.

3.2.2.3 Reduce Vehicle Use

The most direct way to reduce emissions from motor vehicles is to reduce their use. The effectiveness of measures which reduce VMT are potentially limited only by the amount of travel which is autocaptive and essential. This general goal can be approached by three types of measures: reduce trip requirements, provide transportation alternatives, and establish vehicle restraints. The use of vehicles cannot be significantly restrained without providing some alternative means of transportation. A corollary appears to be that significant mass transportation ridership increases do not occur without some form of natural or artifical vehicle restraint.

Reduce Trip Requirements - An essential part of air pollution episode procedures, this measure is implemented when certain air pollution alert stages are reached. Emergency closing of offices, schools, etc. eliminate them as destinations, in turn, eliminating the trip requirement. As a general measure, there are no present means available to effectively reduce trip requirements. Trip generation is built into life styles and land use patterns, therefore, it is not possible to dramatically alter the number or types of trips in our time period of interest. Positive land use policies could channel future development into concentrated nodes each containing a full range of urban activities with walking the primary linkage. Such a land use program would not likely have a substantial impact until the later decade of this century or beyond.

As described in an earlier section, a four-day work week would reduce work trip requirements, but would probably induce increased recreational and other trips.

Another possible approach to reducing trip requirements is a subsitution of communications for travel. Communications technology has already replaced the need for travel in certain occupations. Daily over 13 million shares are traded on the New York Exchange, predominately via telephone and telecommunications, without direct personal contact. Another parallel phenomena is the degree to which computerization is changing the entire business world. Computer installations at widely scattered points are now linked into extensive computer utility networks. Information may be input at Los Angeles, processed in Houston, and transmitted for printing in Washington, D.C. No travel or deliveries are involved - all through electronics technology.

These kinds of operations are spreading rapidly and may be expected to continue. The important question is whether substitution can lead to actual decreases in travel. Recent experience would seem to indicate to the contrary, considering the substantial increases in urban travel over the past two decades, even as television, space satellites, computer technology and other advances in telecommunications came into being. In any event, it is certain personal travel requirements will not diminish in the short time period this study covers.

Provide Transportation Alternatives - Since personal travel requirements cannot be diminished, some form of transportation alternatives must be provided if vehicle use is to be reduced, particularly if vehicle restraints are implemented. These alternatives can be in the form of public transit, and could include schemes to increase individual vehicle utilization such as car pool incentives or jitney cabs (a formal (paid) car pool or informal taxi).

- Public Transit - The current public transit system in Houston is a conventional bus operation providing fairly extensive area coverage. It has 25 radial routes to and through the Houston CBD and five crosstown lines.* The system is well run, having higher average operating speeds than most transit systems in urban areas of this size. It incorporates such innovative improvements as exclusive bus lanes on CBD streets. Public transit serves nearly 80,000 passengers on the average day, almost 85% of whom are captive riders. Primary ridership is to and from the Houston CBD which accounts for 45% of system patronage. An additional 15% of daily ridership travels to and from the Houston Medical Center - Rice Institute - University of Houston complexes south of the CBD. Level of service (area of coverage, headway, etc.) and ammenity improvements (air conditioning bus stop shelters, etc) could result in significant patronage increases, but it is unlikely that such improvements would induce major shifts of choice riders from autos to transit.

A major transit improvement program for the Houston area is currently in the final stages of plan definition. Stage One of the plan consists of 40 miles of rapid transit routes in 7 corridors (4 fixed guideways and 3 busways) including a downtown subway, a number of new semi-express freeway and local bus routes, a number of bus priority routes, route extensions into adjacent counties and secondary distribution systems at major activity center stations. The $800 million program is recommended for immediate implementation with the Stage One system scheduled for completion late in this decade or shortly after 1980.

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*This discussion centers about RTL which serves about 98% of the region's transit passengers.

This program constitutes an order of magnitude improvement over existing transit service. It should attract significant numbers of choice riders from their autos to transit and will provide an acceptable alternative travel mode for those forced from their private vehicles, particularly if restrictive vehicle measures are imposed for air pollution control purposes. The chief questions are: Can the program be accelerated so as to be in full service by the deadline for meeting the 1977 Federal air quality standards? If not, how much of the system could be in service by 1977 and what shifts from auto to transit can be projected for the partially completed system as of that date? It appears highly doubtful that the Stage One system could be completed by 1977 without massive front-end expenditures and commitments. The rapid transit busway and guideway elements require substantial lead time for final design, right-of-way acquisition, construction, and break-in to full service. These tasks almost certainly cannot be completed in four years from the date of this writing. The elements which probably cannot be completed in this time frame are those to which the order of magnitude improvement in level of transit service and the major shift of choice riders from auto to transit must be primarily attributed. Elements of the plan which could be completed by 1977 mainly involve improvements and innovations in conventional bus operations. Although these should yield substantial patronage gains and social benefits, their payoff in terms of automobile related air pollution reductions are marginal and difficult to quantify.

- Car Pools - The average occupancy of autos in the Houston CBD during commute periods range between 1.29 and 1.35 persons per car, and is likely lower for commute trips to other employment concentrations. Greater efficiency (higher occupancy) in auto use through shared trip making, could significantly reduce VMT and hence, automobile emissions. The public attitude survey conducted in the course of this project indicates that nearly 40% of the respondents are interested in work commute car pooling (see Appendix G). Near 10% are already in car pools. Less than 20% of the respondents, not including those already in car pools, felt they might be able to join an existing or organize a new car pool. One of the obstacles to car pooling is informational, i.e., making persons with similar trip requirements known to one another. This information can be provided by computer matching of persons interested in car pooling. Institution of such matching services is recommended. Large employers should also encourage car pooling by providing "pooling boards" in their establishment. Experience indicates that information alone does not encourage substantial levels of car pool formation. More effective are car pooling time and cost incentives or disincentives against driving alone. Exclusive bus lanes offer the one possibility of travel incentives to car pools. Where such lanes are presently provided, they are generally not used to full capacity by the buses and could be shared by autos carrying three or more persons. Effectiveness of this joint exclusive lane use has been demonstrated, most notably on the San Francisco Bay Bridge. Where exclusive freeway bus lanes are planned or in operation, it is recommended that considerations be given to permitting joint use by cars carrying three or more persons. Similarly, where bus priority is established at freeway ramp metering locations, it is recommended that priority be extended to cars occupied by three or more persons. It is difficult to provide positive parking incentives for car pooling, as the driver may drop passengers blocks from his final destination and will thus have no patent evidence that he qualifies for special parking incentives. Uniformly higher parking costs constitute an incentive to car pooling in that they tend to make driving and parking an economic hardship. Any measure which raises the cost of auto travel could be considered an incentive for car pools and mass transportation.

Vehicle Restraints - A number of measures have been identified which will reduce vehicle use (VMT) by prohibiting or discouraging auto traffic from specified areas or discouraging auto travel directly. Many of the measures are oriented towards the CBD because it is a high concentration area and because transit service provides an acceptable alternative for travel to, from and within the CBD. Other measures that could be imposed regionwide or in selected areas include the direct regulation or road use, fuel use, or auto ownership.

- Vehicle Free Zones - Ban all vehicles from a few blocks (pedestrian mall treatment, superblocks) or from an extensive area of concentrated urban activity and you have vehicle free zones. Such zones obviously eliminate localized emission concentrations but potential contribution to areawide reductions are limited by a number of factors.

To maintain the economic vitability of the "free zone," whether large or small, copious parking is normally provided on the fringes.

Since most travel consists of getting to and from the zone rather than within it, emission reductions in terms of regional requirements, are small. Vehicle free zones, particularly large scale ones, could induce significant shifts from auto travel to transit ridership, especially with implementation of Stage One of the Houston Transit Action Program which will provide attractive service with rapid accessibility to the central area. Such shifts produce more meaningful reductions in VMT as they eliminate the whole auto trip. However, the extent of such potential mode shifts is difficult to project. Large vehicle free zones may require internal distribution systems (people movers) to facilitate movement from transit stations or fringe parking areas to actual destinations. A drawback to large vehicle free zones is the tendency to induce congestion (and higher emissions) on streets fringing the "free zone."

Overall, vehicle free zones make a positive contribution to mobile source emission reduction. No reduction credits resulting from this measure have been quantified as no specific proposals for vehicle free zones have been developed. However, such zones are encouraged wherever they respond to other planning goals and objectives.

- Parking Control - This family of measures has the objective of reducing VMT by inducing car pooling, and shifts to public transit through price increases and reduced parking availability in major activity centers.

As with vehicle free zones, this measure is likely to induce significant shifts to transit, particularily after completion of Stage One of the Houston Transit Action Program. Shifts to car pooling would also occur, but the extent of these shifts are difficult to project.

Several drawbacks and implementation obstacles are apparent. The price-demand relationship of parking is not well understood, but experience in cities with close parking supply-demand relationships and high parking fees (daily rates of $2 and up) indicates that parking demand (auto use) is relatively insensitive to price.

When parking controls (pricing or availability limitation) are in force, motorists tend to drive to the fringe of the restricted district and park. An additional negative impact is that more low-speed VMT may be generated by vehicles circling the blocks seeking the scarce spaces.

Parking pricing or reduced availability schemes might reduce property values and retail trade in areas where they are imposed. This would reinforce the tendency to decentralized future development activities. This is unlikely in Houston because the core area has substantial vitality and attractive transit services will be provided with implementation of the Stage One Transit Action Program.

Despite these drawbacks, some parking control measures are desirable to induce car pooling and shifts to transit in the Houston CBD and other activity concentrations which are now or will be served by adequate public transit.

- Tolls - One measure often proposed to discourage vehicle travel is road use regulation. The imposition of tolls on freeways is the method most often put forward for regulating road use. The design of the urban freeways and expressways in the Houston area makes conventional tolling inefficient. Freeways are designed to provide maximum accessibility without compromising the level of traffic service. Access ramps tend to be numerous and closely spaced and would require construction of a large number of toll stations. Besides being extremely expensive to construct and operate, increased emissions due to stop and go operations at numerous toll stations could outweigh emission reduction gains that might result from reduced VMT. Advanced tolling systems using electronic detection or identification of vehicle, with computerized monthly billings are technologically feasible and might eliminate some of the drawback of conventional tolling (i.e., operational cost and emissions due to delays). Such a system would loose much of the psychological deterent of conventional tolling - the act of stopping and paying the toll out of the pocket. It is possible that a high percentage of those priced off the freeways by tolls may drive on surface streets rather than shifting to car pools or transit. This could produce increased emissions as a result of reduced travel speed and idling on surface streets. Tolling measures tend to be regressive. Those priced off the roads will primarily be low income persons. For the above reasons imposition of tolls on Houston area freewavs is not recommended as a means of reducing VMT.

- Ramp Metering as a Restrictive Control - Ramp metering has been developed and already extensively applied in the Houston area for optimizing the efficiency of traffic movement in a freeway corridor. It may be possible to adjust the metering to maximize the difference between emission reductions possible by causing shifts to transit through long delays in entering the freeway and emission increases due to delays and increased travel on slower moving surface streets. Potential effectiveness of this scheme requires detailed study in each freeway corridor but its exploration is recommended. Metering also has potential utility for shutting down the freeway for episode control, and as a means to provide preferential entry for vehicles that have a higher utilization (car pools, buses).

- Moritorium on Traffic Improvements - Several factors mitigate against schemes to reduce VMT by permitting traffic service conditions to decay, thereby encouraging shift to transit or discouraging auto trips from being made at all. Although the proposed Transit Action Program plan includes extensive transit operations and exclusive rights-of-way, conventional transit service elements will be operating on the same streets as autos and would be negatively impacted. Experience at most U.S. cities confirms the motorists' dogged determination to drive in spite of seeming intolerable levels of congestion. Added to the safety compromise which would occur with a moritorium on traffic improvements is the fact that VMT reduction due to shifts to transit could be outweighed by pollution increases due to the increased auto operations in the low speed, high emission ranges.

- Tax Disincentives - It is very difficult to access how a tax on various elements of driving will affect vehicle mileage. There have been suggestions to charge a "pollution" tax in direct ratio to the emission rate and mileage of each motor vehicle or to increase the tax on gasoline (consumption varies directly to mileage). Schemes to reduce vehicle mileage through gasoline pricing are not very effective. Even though the demand elasticities of gasoline are not well defined, it appears that major increases (perhaps doubling the price) do not appear likely to affect consumption. This is borne out by the staggering increases in European auto travel even with fuel costs double those in the United States. People are willing to pay for the convenience of using their cars. Pricing schemes of this type are indiscriminately imposed on all segments of society but the largest impact is felt by the limited income groups.

Various taxes on the automobile have been proposed. These range from minor taxes of $5 to $10 a year for raising mass transit revenues to stiff registration fees of $500 a year. A variant of this proposal is to place substantial registration fees on second or third family autos. Low fees are not effective in reducing VMT; high fees on first family autos are extremely regressive. Low income persons are hit hardest. High taxes on second family autos might provide reductions in VMT and still avoid some of the more regressive elements of this type of taxation. However, there is no method presently available to estimate the reduction potential or demand flexibilities of this type of measure.

The public attitude survey, reported in Appendix E, indicates there will be rigorous objections by the public to any of the more restrictive measures described above. Even though measures which cost less would not be effective in reducing VMT, they should be given consideration as a means to obtain revenue for mass transit.

- Gasoline Rationing - Gasoline rationing is a direct restraint on vehicle mileage and therefore emissions. There are a number of approaches to administrating such a program. One general set of measures are based on control at the source of gasoline production; the other measure approach regulates gas consumption at the consumer (World War II type rationing). Regulating gasoline sales at the manufacturing or wholesale level is a simpler task; however, without price controls gas rationing in this form becomes a gasoline pricing scheme that tends to be extremely regressive with the potential for apparent profiteering that would probably make this method highly objectionable to the public. World War II type rationing also has its drawbacks, particularly in its administration requirements. Appendix H presents a brief history and description of World War II rationing. This direct type of restrictions would probably be the most even handed approach if it were administered through an efficient agency utilizing computers and credit data procedures similar to those developed by the major Banks and credit card organizations.

Any direct vehicle restraint will be extremely objectionable to the public. However, should one be required, gas rationing appears to be the most effective, flexible and even handed approach. It can be started, adjusted to changing requirements, and terminated easier than any other identified direct restriction.

4. PROPOSED CONTROL STRATEGY

There is no adequate definition of the actual effect emission levels have on ambient air quality in the Greater Houston Area. The present air quality measurements and the accuracy of the emission inventory are not sufficient to develop this relationship. Even if the data were available, the time restraints of this study made it impossible to utilize the sophisticated mathematical modeling techniques required to accurately estimate and project the relationship. Therefore, the control strategy recommendations are based on proportional rollback techniques that relate estimated existing emissions and air quality on a proportional basis. This is not an adequate basis for implementing high impact measures.

The proposed strategy is phased so as to take advantage of legislative or judicial remission, technology development and changing requirements as the result of a better understanding of the air pollution problem in the Greater Houston Area. In its fully implemented form, it will allow air quality standards to be met by the 1977 due date. Phase I measures have substantial justification either in terms of significant air quality improvement or other urban needs. The present justification for Phase II measures is tentative at best. The decision to implement them must be based on a demonstrated need for further hydrocarbon emission reductions, and a thorough evaluation of each individual measure in terms of the needs of the people in the Greater Houston Area. This study had neither the time nor the data base sufficient to fully assess the social, political and economic impact implied by the Phase II measures.

Phase I Measures:

1. Continue evaluation of control measures - Expand the air monitoring program in the Greater Houston Area to include more stations and gas chromotography at selected stations. Initiate a regular (yearly or bi-yearly) review of the air quality and emission inventory data to determine if adjustment of the emission control strategy is required to meet ambient air quality standards.

2. Stationary source measures - Tighten and expand the Regulation V stationary source controls as recommended by the Texas Air Pollution Control Services Study.(4) Broaden the coverage of Regulation V to include all counties in the region.

3. Mandatory inspection/maintenance - Implement an annual inspection/maintenance program for in-use vehicles. This measure provides significant reductions in motor vehicle emissions and is necessary to obtain full benefit from the Federal new car emission controls. An emission inspection performed along with the annual safety inspection would be the simplest system to implement. Since the present safety inspection is performed at franchise stations and garages, the inspection procedure should be an idle emission test with mandatory maintenance required upon failure. This method is recommended because it has lower start up and training costs, and can be easily adjusted as more emission data becomes available. A strong consumer protection element should be added to the safety/emission inspection program. An upper limit on the amount of money a person is required to spend on bringing his automobile into compliance with emission regulations should be considered as a built-in consumer protection feature.

4. Mass transit - A substantial improvement in mass transit is required in the Greater Houston Area. The contractor for the Houston Transit Action study enjoys an excellent reputation in the field of transportation planning, and has outlined a comprehensive mass transit program. Based on the need for improved mass transit and recognizing the extensive studies that have been performed, it is recommended that Phase I be implemented immediately.

5. Parking measures - It is recommended that the following parking measures be instituted in all high density areas: (a) strictly enforce existing parking regulations, (b) eliminate preferential rates for all-day parking, (c) review existing parking availability and develop regulations to control development and pricing of off-street parking,

(d) as Phase I of the Houston Transit Action Program comes into operation, increase parking costs in the CBD and other major activity centers.

6. Car pool incentives - (a) Initiate a formal public information program with the aim of increasing the amount of voluntary car pooling. (b) Enlist the cooperation of government agencies and large corporations in providing preferential parking and/or other incentives for employees who choose to car pool. (c) Initiate a pilot computer matching program for potential car poolers to identify the type and amount of data required to provide matching information on a large scale. Although this type of program will probably not induce a substantial shift to car pools, experience in administering an information program will be required in case restrictive driving measures are needed before adequate public transportation is available. Better utilization of the private automobile fleet would be the only transportation alternative available in that situation.

7. Fugitive and evaporative emission controls - (a) Promulgate regulations to control evaporative hydrocarbon emissions from all gasoline marketing levels. (b) Promulgate regulations to control all reactive hydrocarbon emissions from solvent users. (c) Promulgate regulations to reduce fugitive losses from all process industries. Fugitive losses account for approximately 50,000 tons/year emissions in this region. It is reasonable to assume that a rigorously enforced fugitive emission regulation should be able to reduce this figure by approximately 20%, or 10;000 ton/year.

Figure 4-1 summarizes the emission reductions possible from implementation of Phase I. Present total hydrocarbon emissions are approximately 525,400 tons/year. The goal is to reduce emissions to approximately (~) 131,000 tons/year by 1977. Present regulations and Federal motor vehicle controls will reduce emissions to ~349,000 tons/year. Application of a tightened Regulation V (measure 2) should reduce emissions to ~204,000 tons/year. Inspection/maintenance (measure 3) can be expected to reduce this total to ~198,000 ton/year. Implementation of the Houston Transit Action Phase I, parking restrictions, and car pool incentives (measures 4, 5 & 6) can be expected to reduce VMT by 3 to 5% in 1977. This VMT reduction results in total remaining hydrocarbon emissions of approximately 190,000 tons/year , for an overall Phase I reduction of approximately 64% from the 1972 emission level.

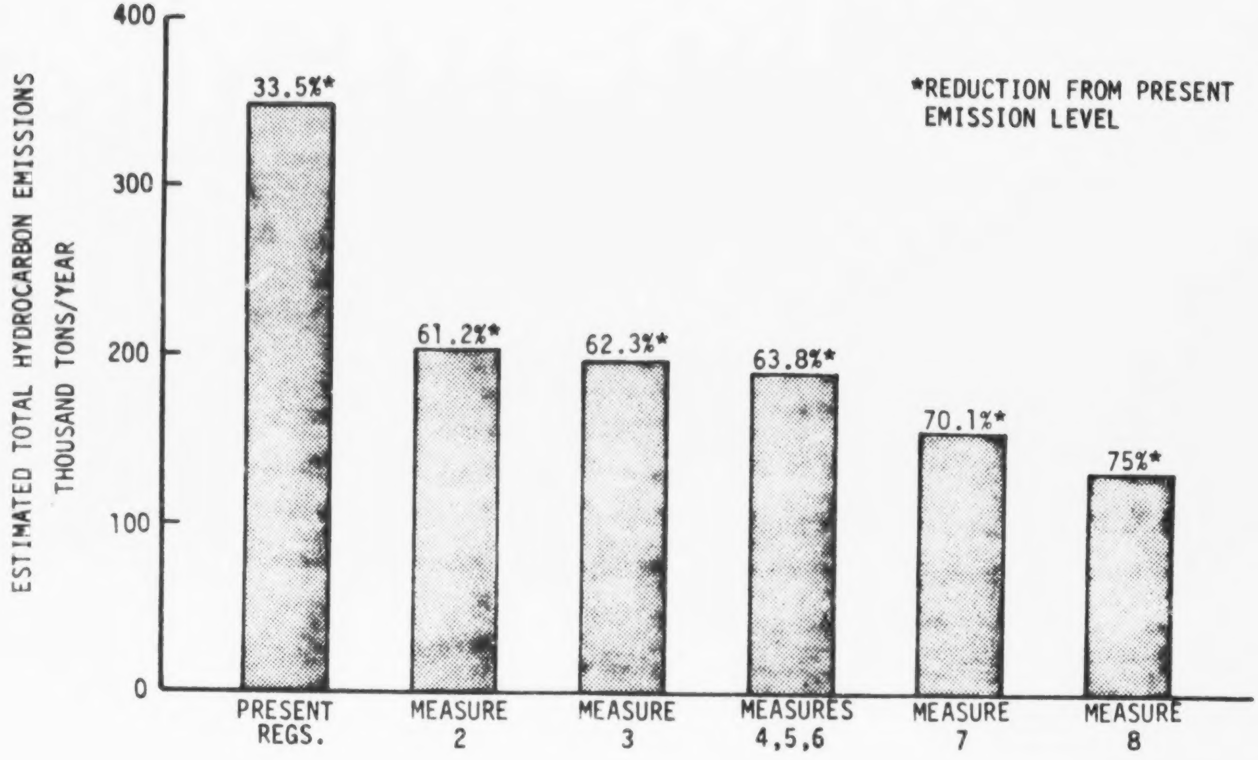

Figure 4-1. Estimated Total Hydrocarbon Emissions in 1977 Resulting from the Proposed Control Measures

Application of Measure 7 should result in a total hydrocarbon emission of approximately 157,000 tons/year in 1977. This corresponds to an approximately 70% reduction from the 1972 baseline.

No retrofit strategies were recommended for Phase I because the only effective, low-priced retrofit was the VSAD/LIAF for pre-1968 automobiles. In 1977 pre-1968 autos will be less than 10% of the total vehicle population. Since the average reduction per vehicle is only about 20% of the exhaust hydrocarbon emissions, the overall impact of the measure would be less than a 1% total hydrocarbon reduction. The administrative and enforcement cost for a retrofit program are not justified for this magnitude of reduction. A catalytic converter retrofit is very effective, however, the costs and obstacles associated with such a retrofit place it in a Phase II situation. Further study is required before a commitment to this magnitude of a retrofit would be unequivically recommended.

Phase II Measures

If at the end of the evaluation period in 1975 it is determined that additional hydrocarbon emission reductions are required, those reductions will probably have to come from motor vehicles. Measures 2 and 7 provide for maximum technology control of stationary sources. One of the most significant findings of this study is that improved mass transit and other incentives will not lure people from their cars in sufficient numbers to make major strides toward achieving the 1977 air quality standards nor will pricing disincentives force reduced auto travel levels on this order of magnitude unless costs extremely regressive to certain segments of the population are imposed. In light of this conclusion, two complimentary methods for reducing automotive pollutants remain.

8. Motor vehicle emission reduction - (a) Retrofit catalytic converter on all 1968-1974 automobiles and reduce the vehicle miles traveled during the summer and fall months by 30% or (b) no major vehicle retrofit program and reduce vehicle miles traveled by 50% during the summer and fall months. The method recommended to affect the vehicle mile reduction is gasoline rationing.

As is obvious, implementation of the Phase II measure would be very difficult. Rigorous objections at all levels of government, industry, and from the public can be expected. For that reason, implementation is not recommended unless and until the need for the additional (over Phase I) hydrocarbon emission reductions are substantiated by further ambient air quality monitoring and, also the air quality standards are fully reviewed in light of the cost to achieve them.

4.1 OBSTACLES TO IMPLEMENTATION

The relative significance of obstacles to implementation of the proposed transportation control strategy has been estimated using the following categories.

Technical obstacles - obstacles involving the design of hardware, details of administrative procedure, or specification of standards or acceptance limits necessary for implementing recommended control measures.

Legislative obstacles - obstacles involving writing and passing laws, rules, and regulations required for instituting and administering control measures.

Socio-economic obstacles - obstacles involving the impact of control measures on the public, commerce, and industry.

Political obstacles - obstacles involving the feasibility of of productive interaction among appropriate leaders, administrators, legislators, and special interest groups for the purpose of instituting recommended control measures.

In general, there appear to be few obstacles that would limit implementation of the Phase I control measures. Stationary source reductions probably have the fewest obstacles and they are generally technical and socio-economic in nature. Careful evaluation of requirements and care in writing the resulting regulations may be sufficient to overcome these obstacles. Mandatory inspection/maintenance may encounter a few moderate political obstacles depending on the shape the proposed program eventually takes. The public attitude survey shows that the public supports this type of measure. The parking measures could also meet with local opposition from commercial and business interests. The mass transit program appears to have wide public support. There is some difficulty in finding the start button, however. It is not clear whether the implementation obstacles are socio-economic in nature (where does the money come from), or political. There certainly appears to be no major legislative or technical obstacles involved with mass transit.

The obstacles to implementing the Phase II measures are substantial, even from a cursory examination. Both the major automobile retrofit and the gasoline rationing measure elements will encounter obstacles of major significance in the socio-economic, political, and legislative categories.

Gas rationing will be the most controversial and will encounter the greatest amount of debate regarding public acceptance and political feasibility of all the measures proposed. Justification for proceeding with implementation of the Phase II measure must be substantial and visible (either in terms of health effects or property damage) before any relaxation of the political or socio-economic obstacles can be expected.

4.2 IMPLEMENTATION PROCEDURE AND TIME SCHEDULE

The schedule for plan implementation is shown in Table 4-1. The table is generally self explanatory. It assumes acceptance of the proposed plan and indicates date for plan completion, approval, and necessary legislation. Pollution control measures are listed separately and dates for their implementation are indicated. The following are highlights of the implementation schedule.

1. A formal air quality review and action plan procedure should be initiated to operate on the expanded air quality surveillance program information and yearly updates of source emission data. Decisions to proceed with the more restrictive measures must be based, at least in part, on information supplied via such a formal review.

2. New stationary source controls have been recommended. It is proposed that Regulation V be revised as recommended by the Texas Air Pollution Control Services study. The revised regulation should be adopted by July 1973 with the final date for compliance in July 1976.

3. The inspection/maintenance program requires enabling legislation in order that it may be performed in conjunction with the Department of Public Safety's annual safety inspection. The proposed schedule calls for detailed program design to be complete by July 1973; for a pilot program to be complete by January 1975; and mandatory emission inspection to begin region-wide by July 1975.

4. Implementation of the mass transit program falls outside the responsibility of the Texas Air Control Board; however, it is recommended that Phase I of the Houston Transit Action Program be

Table 4-1. Proposed Implementation Plan Schedule

Element	1973	1974	1975	1976	1977	1978	1979	1980
Revised Implementation Plan Submitted to EPA (Feb. 15, 1973)	▲							
Formal Air Quality Review Procedure and Action Plan Initiated (Measure 1)	▲	▲	▲	▲	▲	▲	▲	▲
Legal Requirements of Plan								
Texas Air Control Board								
• Obtain enabling legislation for inspection/maintenance and retrofit	▲							
• Obtain enabling legislation for gasoline rationing				▲				
HTAP Administering Agency								
• Obtain legislative charter	▲							
Air Quality Surveillance Program Expansion (Measure 1)	—	▲						
New Stationary Source Controls (Measure 2)	▲	—	—	▲				
• Adopt revised Regulation V	▲							
• Compliance schedule required from facilities existing before July 1973		▲						
• Final date for compliance				▲				

Table 4-1. (continued) Proposed Implementation Plan Schedule

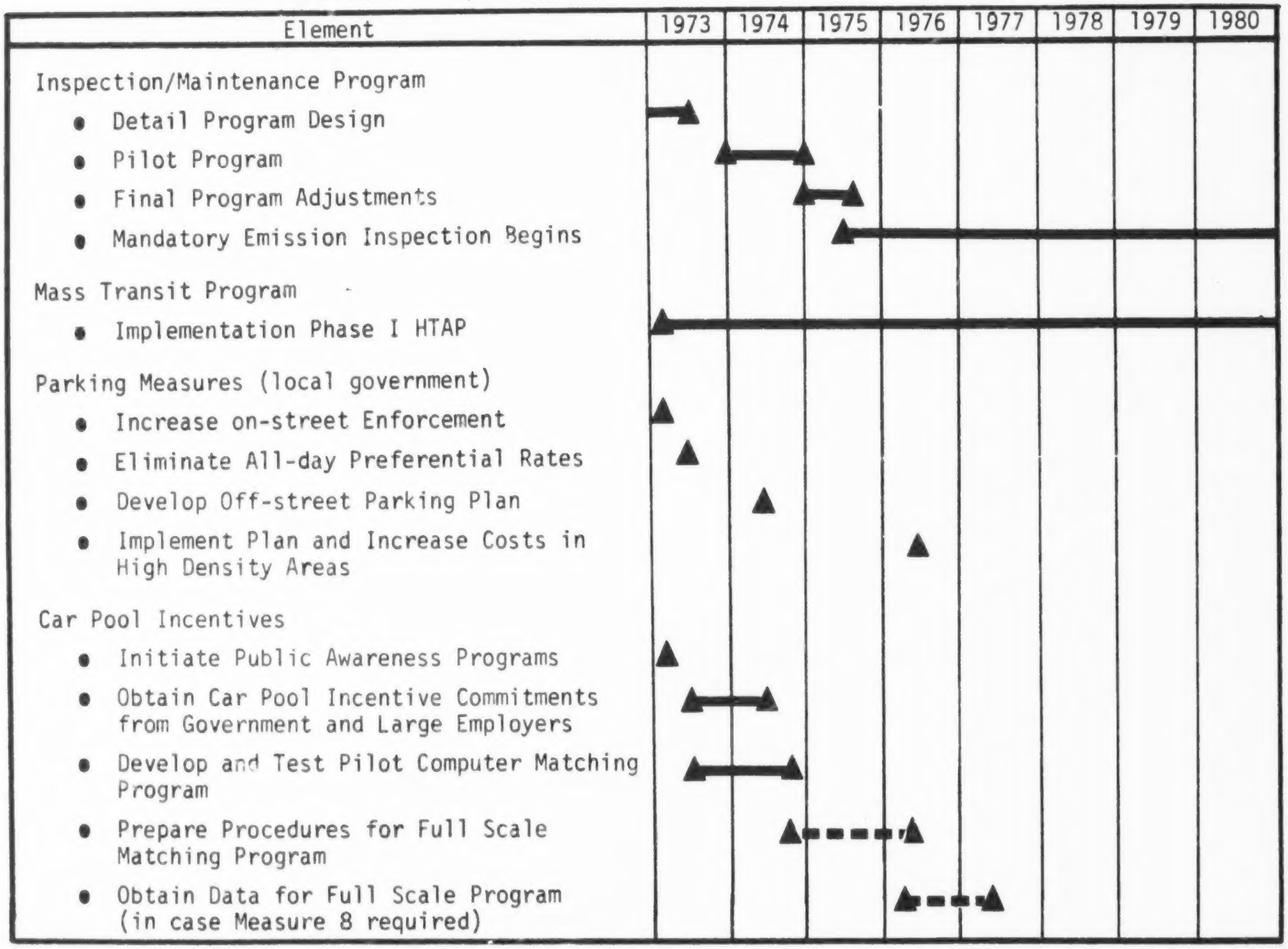

Table 4-1. Proposed Implementation Plan Schedule

Element	1973	1974	1975	1976	1977	1978	1979	1980
Fugitive and Evaporative Hydrocarbon Emission Controls (Measure 7)			▲━━━	━━━━	━▲			
• Adopt Necessary Regulations			▲					
• Compliance Schedule Required			▲					
• Final Date for Compliance					▲			
Motor Vehicle Emission Reduction (Measure 8)								
• Retrofit 68-75 Vehicles with Catalytic Converter System			▲▬▬	▬▬▬	▲			
• Develop Gasoline Rationing Procedures and Administrative System			▲▬▬	▬▬▬	▲			
• Implement Gasoline Rationing June thru September yearly					▬▬	▬▬	▬▬	▬▬

Phase I ━━━━━

Phase II ▬ ▬ ▬ ▬ ▬
(if required)

implemented as soon as possible. Its importance cannot be overemphasized. If the more restrictive transportation measures are implemented, a significant improvement in public transit will be needed to provide alternative means of transportation.

5. Parking measures generally fall under the auspicies of the local governments. These local governments should be made aware (through the planning offices of the Texas Air Pollution Control Services) of the basic need for the parking measures.

6. A general program to explore computer matching and to provide support for other types of car pool incentives is necessary. The program elements scheduled in the mid-1970s are included in case more restrictive automobile controls are required, making large scale car pooling mandatory (in lieu of wide availability of public transportation).

7. Additional fugitive and evaporative hydrocarbon emission control regulations would have to be adopted by the beginning of 1975 in order to meet full compliance by mid-1977.

The remaining elements of the proposed implementation schedule are part of the Phase II proposed measure. Decisions to proceed with their implementation should occur as a result of the formal air quality review process.

8. A major vehicle retrofit would require a minimum of two years to complete. The retrofit decision must be made prior to July 1975 so that sufficient quantities of retrofit devices are available and adequate information can be disseminated to the service/garage industry. Detail study of gasoline rationing procedures and the development of an administering system would be required before gas rationing could be implemented. If required, the first gas rationing period would be June through September 1977, and would occur every year following or until other hydrocarbon emission reductions were sufficient to meet ambient air quality standards without gas rationing.

4.2.1 Implementation Surveillance

The proposed control strategy must be considered as an initial attempt to quantify the relationship between industrial and transportation processes, and the regional air pollution problem. The formal yearly air quality review will be the checkpoint assessment that is needed to provide appropriate adjustments to the control strategy. The following types of data will be required for this process:

- Ambient Air Quality Measurements
- Updated Emission Inventories
- Transportation Data (Traffic Projections)

Formal programs and procedures have been instituted to collect air quality and emissions data and report them to the Environmental Protection Agency (via the semi-annual report). The data from the expanded air quality network (Measure 1) should automatically be included in this process. Updated motor vehicle emission factors should be utilized as they are developed from the on-going EPA testing programs.

Provisions should be made for H-GRTS, the regional transportation coordinating agency, to regularly report traffic data to the Texas Air Pollution Control Service. Until 1975 the reporting requirements would consist of yearly estimates of average areawide VMT stratified by vehicle type, with estimates of VMT variations by day of week and month of year; and estimates of distribution of VMT by travel speed ranges. Appropriate arrangements would be necessary to insure input of necessary data by local jurisdictions to H-GRTS for compilation. After 1975, if it appears Phase II measures are required, more frequent reporting would be needed to estimate and monitor effectiveness in achieving specified VMT reductions. Development of a simplified method for estimating areawide average daily VMT on the basis of selected sample counts appears desirable to minimize time, effort and cost of the more frequent reporting. Following is a suggested traffic surveillance program for implementation in this case.

- Identify a selected number of traffic counting stations (probably no more than 30) which can be regularly monitored and from which accurate estimates of areawide average daily VMT can be made. Use of permanent count stations with induction loop counters appears desirable.
- Develop factors for estimating areawide daily VMT on the basis of the count sampling.
- Conduct counts and estimate average areawide daily VMT every 3 months and report this data to the Texas Air Pollution Control Service.

Computer analytical simulation techniques using models now under development, should be utilized to better assess the relationship of emissions and air quality. Once calibrated, computer models can predict the effects of proposed actions with high confidence. This would not only be a valuable tool for strategy assessment, it would assist in regional planning (permit application review) and enforcement.

4.3 AGENCY INVOLVEMENT

The Texas Air Control Board is the primary agency for implementation of all measures proposed in this report. The Board has supra-management responsibility for (1) administration of contract and grant programs involving air pollution in the state of Texas, (2) coordination of air pollution control programs which involve multi-county areas, and (3) representation of Texas in finding the solution to air pollution problems which extend across state lines. The Board presently has the power to appoint task force teams to aid and advise the Board regarding studies and programs specific to certain areas of Texas. The involvement of other agencies in the implementation of this transportation control strategy is necessary in several areas. Table 4-2 summarizes the agency requirements for administration of the proposed measures.

4.4 LEGAL AUTHORITY

Adequate legal authority already exists to control stationary sources as outlined in measures 2 and 7. The legal authority to adopt emission limitations is contained in Section 3.02, 3.09, 3.10, and 3.18 of the Texas Clean Air Act, Article 4477-5, Vernon's Texas Civil Statutes; and regulations of the Texas Air Control Board. Authority to prevent construction, modification, or operation of any stationary source at any location where emissions will prevent the attainment or maintenance of a national standard is contained in Sections 3.27 and 3.28 of the Texas Clean Air Act, Article 4477-5, Vernon's Texas Civil Statutes; and in the registration and permit requirements of Regulation VI of the Texas Air Control Board

Table 4-2. Agencies for Administering Proposed Measures

	State	County/City
Measure 1	TACB	City/County Health Depts.
Measure 2	TACB	City/County Health Depts.
Measure 3	TACB - DPS	---
Measure 4	Highway Dept.	HTAP Agency
Measure 5	--	City/County Law Enforcement City Coucils, County Commissioners
Measure 6	TACB	City/County Health Depts. Civil Defense Offices
Measure 7	TACB	City/County Health Depts.
Measure 8	TACB (retrofit) Administering Agency for gas rationing to be determined	

Legal authority to carry out inspection, testing, and/or retrofit of motor vehicles is contained in Section 3.10(d) of the Texas Clean Air Act, however, further legislation is required to perform the inspection in conjunction with the annual safety inspection.

Adequate legal authority rests with the local governments to implement the parking measures.

Legal authority does not exist to allow implementation of gasoline rationing. However, the Texas Air Control Board has legal authority to to develop procedures and perform necessary planning, Section 3.04 of the Texas Clean Air Act.

APPENDIX A

AIR QUALITY AND EMISSION DATA

A summary of the air quality and emission data used to evaluate the air pollution control measures described in Section 3 is presented in this appendix.

Continuous measurement of gaseous pollutants did not begin in the Houston area until 1971. The Pollution Control Division of the Houston Department of Public Health initiated the first continuous measurement program. The monitoring program began with sulfur dioxide, nitrogen dioxide, and total oxidants measurements. Carbon monoxide and total hydrocarbons were added at the beginning of 1972, and ozone measurements began last May.(20)(21) There have been no gas chromatography studies to determine the relationships and magnitude of the ambient non-methane total hydrocarbon component.

The only emission inventory data available at the beginning of this study were the summary sheets presented in the Texas Implementation Plan.(1) Administrative difficulties within the Texas Air Pollution Control Services and regulations discouraging the disclosure of inventory information to the public, made it impossible to obtain sufficient inventory information to properly evaluate the effects of control measures for stationary sources and make constructive recommendations. These problems have now been eliminated, but not in time to allow a detailed investigation as part of this study. The emissions summary data presented in this appendix and used in measure evaluation are based on the 1969 emission inventory as modified by a recent (still unreleased) Texas Air Pollution Control Services study on hydrocarbon emissions from point sources.(4)

A.1 AIR QUALITY DATA

Air quality data for "Set II" pollutants is summarized in Table 1-A. The figures for carbon monoxide and nitrogen oxides are the same as those reported at the time the Texas Implementation Plan was submitted in January 1972. Measurements taken since that date do not conflict with these figures. There are no identified "hot spots" or problem areas for either pollutant; therefore, more control measures are not required. Any measures developed for other pollutants must not degrade air quality with respect to carbon monoxide or nitrogen oxides, however. The maximums for photochemical oxidants and hydrocarbons are different from those reported in the Implementation Plan. Hydrocarbons are considered only because of their influence on photochemical oxidants. A reduction in the hydrocarbon emissions sufficient to allow photochemical oxidant to meet standards is deemed sufficient even if the specified hydrocarbon standard has not been reached.(2) The listed maximum concentration for photochemical oxidants was measured during a study undertaken by the State of Texas in the upper Texas Gulf coast during April, May and June of 1972.(3) Four ozone measurement sites were in the Greater Houston Area. The sites were located in Lake Jackson, Dickenson, downtown Houston, and the Houston ship channel.

The maximum daily one-hour average for each of these sites is plotted in Figure 1-A. The national standard (.08 ppm) was exceeded a significant portion of the time throughout this study. The longest excursion

Table 1-A. Summary of Air Quality Data

POLLUTANT	FEDERAL AMBIENT STANDARDS	FEDERAL SAMPLE BASIS	MEASURED MAX. IN REGION
CO	10 mg/m^3	8 HR. MAX.	8 mg/m^3
	40 mg/m^3	1 HR. MAX.	15 mg/m^3
PHOTOCHEMICAL OXIDANTS	160 μg/m^3	1 HR. MAX.	630 μg/m^3
HYDROCARBONS	160 μg/m^3	3 HR. MAX. (6-9 A.M.)	3660 μg/m^3
NO_X	100 μg/m^3	ANNUAL ARITH MEAN	103 μg/m^3

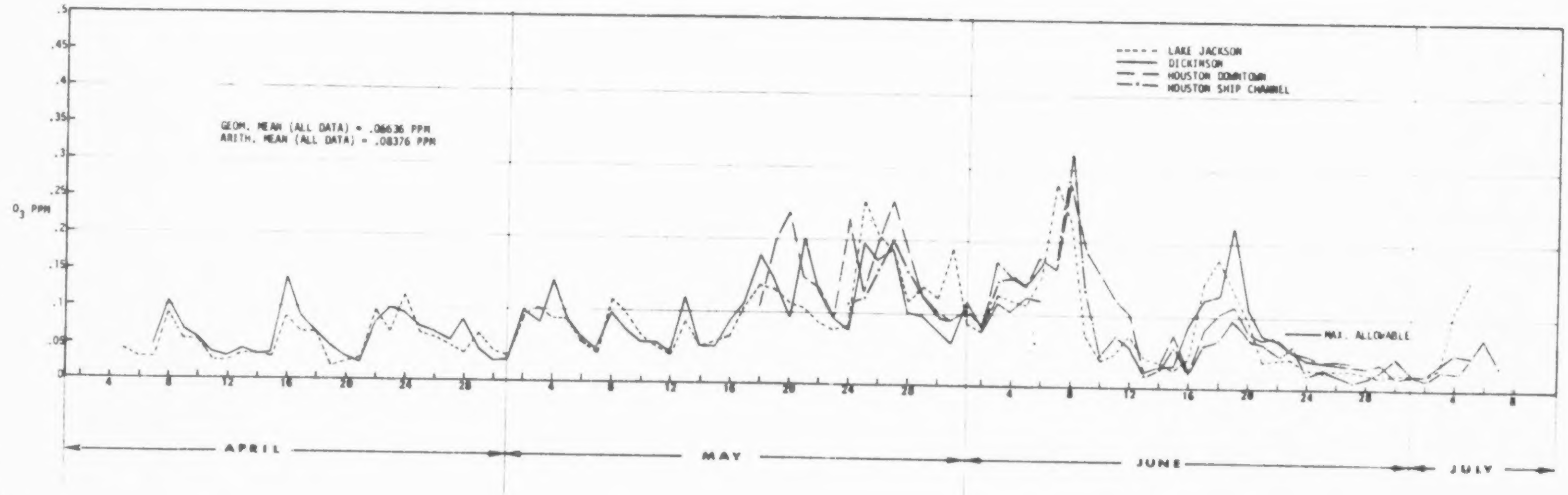

Figure 1-A. Daily Maximum 1-Hr. Ozone Concentrations, Texas Gulf Coast Special Ozone Study

above the limit was for 17 hours at the Jefferson County Airport (outside the Greater Houston Area) on May 29. Abrupt weather changes resulting in several days of rain, June 10 through 16, coincide with the decline in the ozone level after June 10. High ozone readings occur again at all sites around June 19 and 20. However, the low ozone level following this rise was not caused by rain but by other climatic conditions such as unseasonal temperatures and overcast skies. Peak ozone concentrations were usually preceded by zero levels early in the morning. Three air stagnation advisories were issued for the upper Texas Gulf coast during the study. They were May 24 from 1100 hours to May 25 at 1500 hours; June 8, 1100 hours to June 10, 1100 hours; and June 19, 1100 hours through June 20, 1100 hours.

Generally; peak ozone concentrations, and the number of times they exceeded standards, increased as temperatures advanced to full summer intensities. Precipitous changes in ozone concentrations were often found to coincide with wind shifts. Since all monitoring sites experienced high levels of ozone in concert, it appears that there is a unified weather pattern over this coastal area and that the ozone problem is a regional one.

Figure 2-A is a comparison of total hydrocarbons and ozone measurements observed by Houston's continuous air monitoring program.(22) The ozone readings observed at these stations correlate with those taken by the state in the ozone study. The plotted ozone measurements were observed at a monitoring station located on Clinton Drive in Houston. There were no continuous hydrocarbon readings at the Clinton Drive station during this time period; therefore, hydrocarbon measurements taken at the

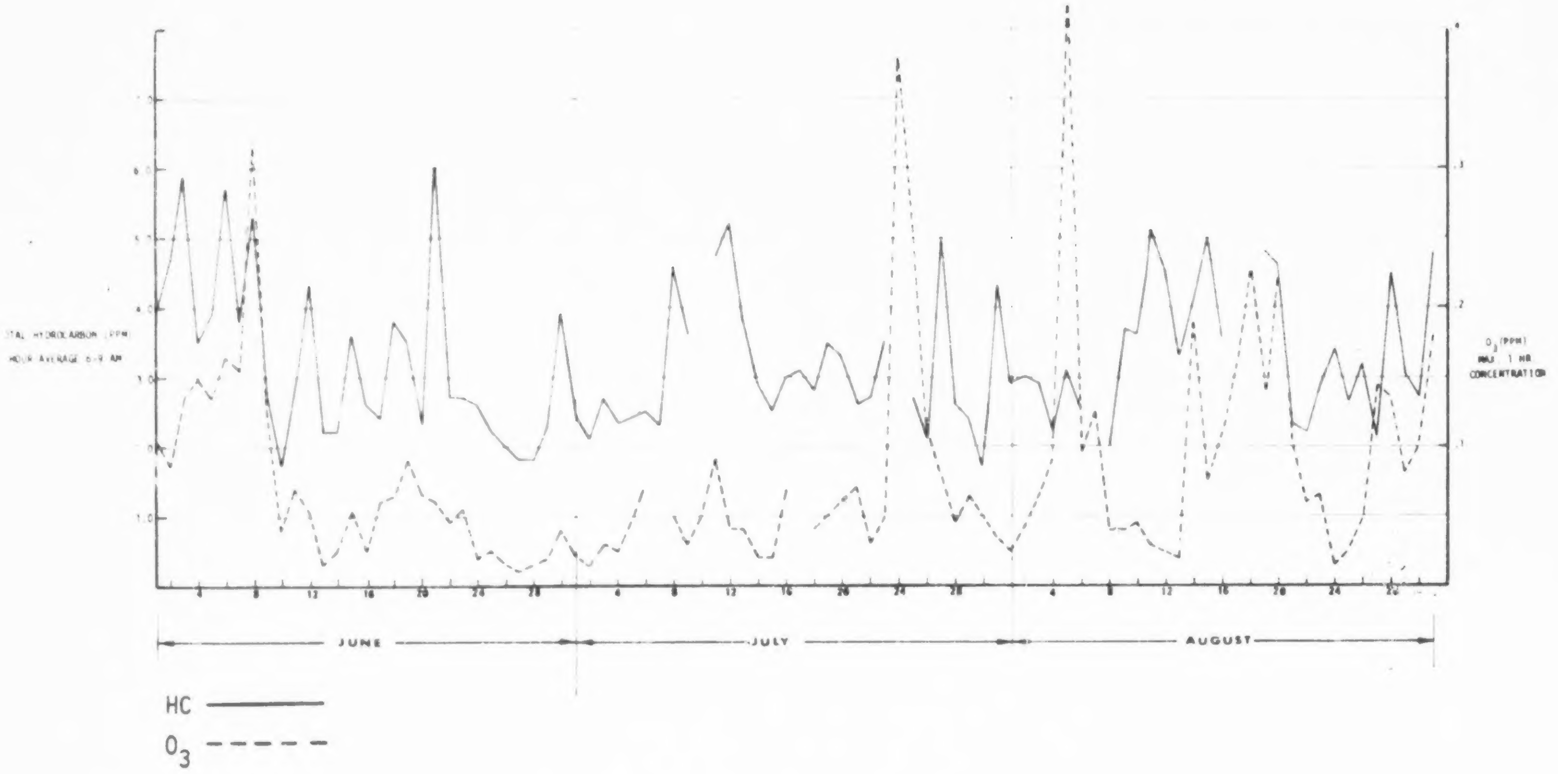

Figure 2-A. Comparison of HC and O_3 Measurements, Houston 1972

Health Department located on MacGregor Street were used for comparison with the ozone readings. As can be seen in Figure 3-A, the available fragmental readings during the period of interest from the Clinton Drive station closely correlate with the MacGregor Street readings.

All available measurement data were manipulated with various statistical routines to see if a significant correlation could be found between the ozone, total hydrocarbons, and various meteorological parameters. Sufficient NO_2 measurements were not available to include them in the effort. Simple correlation techniques could uncover no strong relationship. A stepwise multiple regression technique was attempted; however, there was not enough data to obtain a statistically significant result. This analysis leads to the conclusion that there is not sufficient ambient monitoring data at this time to develop a statistical model for predicting photochemical oxidant air quality.

Since the regulations for photochemical oxidant control are based on hydrocarbon reductions,(2) which are in turn based on an observational model,(23) it was decided to see just what type of observational model could be developed for the Houston area. Figure 4-A is a plot of daily 3-hour average total hydrocarbons versus maximum daily 1-hour average ozone concentrations in the Houston area. The upper dash line corresponds with the same relationship for combined data from Los Angeles, Denver, Cincinnati, Philadelphia and Washington which can be found in Figure 5-1 of Reference(24). As can be seen, a majority of the readings from the Houston network fall significantly under the data presented in the hydrocarbon criteria document.

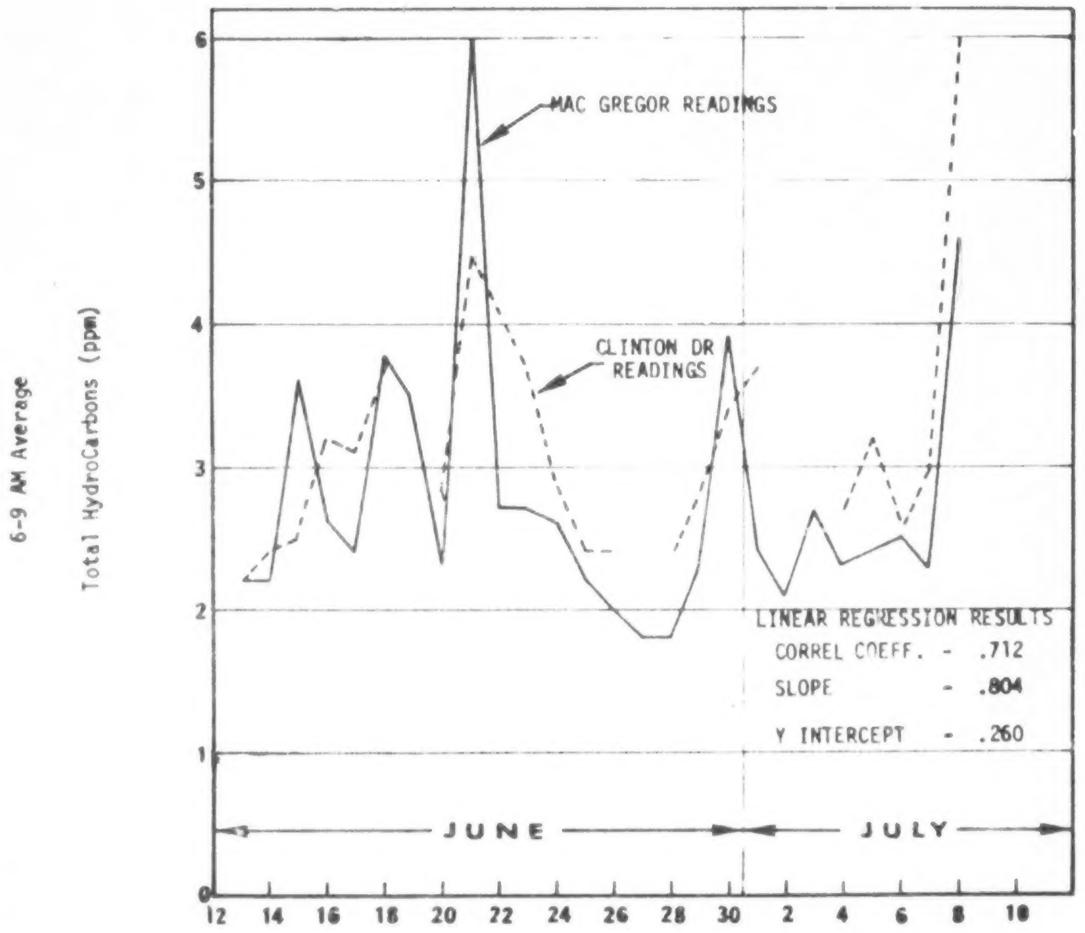

Figure 3-A. Correlation of MacGregor Readings to Clinton Drive Readings

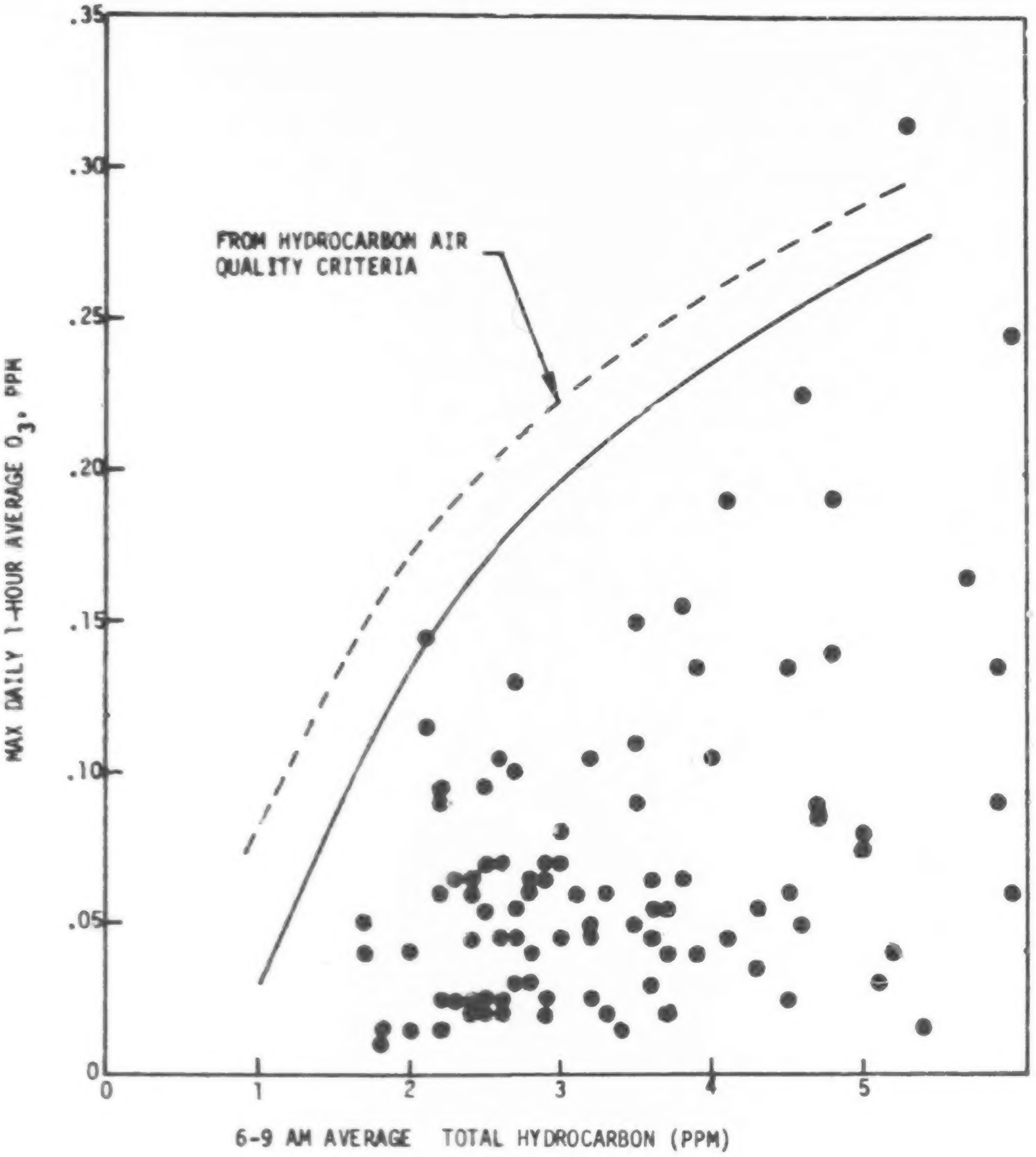

Figure 4-A. Observational Model for the Relationship of Total Hydrocarbons to Ozone in the Houston Area

The lack of correlation between any of the data and approaches discussed above results in the conclusion that the prediction of photochemical oxidant ambient air quality levels is impractical using any modeling approach (statistical, physical, observational) considering the present data base. Therefore, emission reduction requirements will be founded on the Federal regulations alone. Figure 5-A is Appendix J of the Federal Rules and Regulations for the preparation of implementation plans.(2) Based on this appendix, a 630 $\mu g/m^3$ ozone reading requires a hydrocarbon reduction of near 100%. Since this is impractical, EPA has authorized the use of simple proportional rollback. A proportional rollback of photochemical oxidants from 630 to 160 $\mu gm/m^3$ would result in a reduction of approximately 75%. This percentage is also the reduction goal for hydrocarbons.

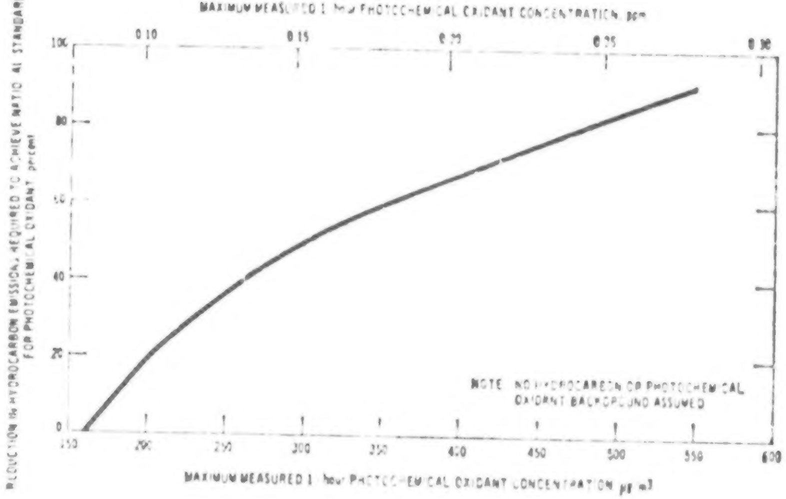

Figure 5-A. Appendix J of Federal Rules and Regulations for Preparation of Implementation Plans

A.2 EMISSION INVENTORY DATA

An accurate emission inventory is the most difficult component of an air quality data base to obtain. Every potential source of air pollution must be located, catalogued, its pollutants identified, and the amount of pollutant emissions estimated or measured. The first statewide inventory was completed in 1969. The emission inventory is updated yearly and becomes more accurate as new sources are identified and catalogued and earlier estimates of emissions are replaced by measurements taken at the source. Because the inventory data used in this study is mostly from 1969, its accuracy and completeness is questionable. However, the deadlines of this study did not allow for extensive additional data collection and the information available must be utilized. A major part of this study was to estimate present and projected emissions from motor vehicles using the latest motor vehicle emission projections; therefore, this emission category(mobile) will not be included here. Tables 2-A through 4-A are emission summaries for CO, NO_x, and HC in the Greater Houston Area. These tables were constructed from the 1969 emission inventory included in the Texas Implementation Plan. Projections of future emissions were estimated from the above baseline using industrial growth data compiled by the Houston Chamber of Commerce and other sources.(1) (4) These projections are presented in Tables 5-A through 7-A, and take into account the reductions to emissions that will occur from the enforcement of present regulations. The hydrocarbon reductions shown are contributable to Regulation V and are based on results of another contractor's study made available by the Texas Air Pollution Control Services.(26) Utilizing the above projection data, calculations

Table 2-A. Summary of Hydrocarbon Emissions for the Greater Houston Area in 1969 (Motor Vehicles not Included)

	Point	Area	Transport*
Brazoria	23,415	600	49
Chambers	818	174	32
Fort Bend	2,203	201	52
Galveston	55,562	500	82
Harris	154,843	5,795	5,945
Liberty	530	381	46
Montgomery	9,725	505	48
Waller	1,460	205	40
Total	248,556	8,361	6,294

Table 3-A. Summary of Carbon Monoxide Emissions for the Greater Houston Area in 1969 (Motor Vehicles not Included)

	Point	Area	Transport*
Brazoria	147,225	1,042	253
Chambers	1,289	520	84
Fort Bend	50	349	95
Galveston	246,603*	891	358
Harris	75,442	14,451	14,320
Liberty	1,458	1,308	163
Montgomery	93,012	1,653	109
Waller	4,857	624	60
Total	569,936	20,838	15,442

*Trains, boats, and planes

Table 4-A. Summary of Nitrogen Oxide Emissions for the Greater Houston Area in 1969 (Motor Vehicles not Included)

	Point	Area	Transport*
Brazoria	12,944	350	68
Chambers	1,366	78	50
Fort Bend	15,376	165	78
Galveston	49,842	520	114
Harris	101,189	5,563	1,015
Liberty	1,457	173	67
Montgomery	1,319	263	72
Waller	1,795	86	58
Total	185,288	7,198	1,521

Table 5-A. Projections of Total Hydrocarbon Emissions from Sources Other than Motor Vehicles in the Greater Houston Area (based on the 1969 emission inventory)

	1972	1975	1977	1978	1980
Point	271,603	141,329	149,936	154,434	163,839
Area	9,136	9,983	10,059	10,909	11,573
Transport	6,877	7,514	7,972	8,211	8,711
Total	287,616	158,826	168,499	173,544	184,123

Table 6-A. Projections of CO Emissions from Sources Other than Motor Vehicles in the Greater Houston Area (based on the 1969 emissions inventory)

	1972	1975	1977	1978	1980
Point	622,784	680,532	721,976	743,635	788,922
Area	22,770	24,881	26,396	27,188	28,844
Transport	16,873	18,437	19,559	20,145	21,372
Total	662,427	723,850	767,931	790,968	839,138

Table 7-A. Projections of NO_x Emissions from Sources Other than Motor Vehicles in the Greater Houston Area (based on the 1969 emissions inventory)

	1972	1975	1977	1978	1980
Point	202,469	221,243	234,716	241,757	256,480
Area	7,865	8,594	9,117	9,390	9,962
Transport	1,662	1,816	1,926	1,984	2,104
Total	211,996	231,653	245,759	253,131	268,546

were performed to determine the total hydrocarbon emissions due to all sources, including motor vehicles, and the estimated reductions possible with the present stationary source regulations and Federal motor vehicle controls. This initial evaluation determined that the ambient air quality standards could not be met by 1977, even with zero mobile emissions, because estimated stationary source reductions were not adequate.

Based on these findings, the Texas Air Pollution Control Services staff reviewed their inventory of hydrocarbons sources in this region, and reevaluated the reductions that might be realized by applying the present regulations and additional proposed restrictions to this category of industrial point sources.(4) This study utilized data for Harris and Galveston counties from the "new" 1970 emissions inventory, from a hydrocarbon emission study by another contractor, and from Section 4 of Appendix B of the Federal Register dated 14 August 1972. The study resulted in a new estimate of hydrocarbon emissions from point sources in Harris and Galveston counties and a recommendation that Regulation V be extended to include ethylene released from consuming plants and expanded to include smaller tanks; and vents not now flared (or otherwise abated) from all of the significant sources in the process industry. Included in this report were estimates of the reduction in hydrocarbon emissions that could be expected with a tightened Regulation V.

The results of the above study were utilized directly to update the point sources for Harris and Galveston counties in this investigation; however, the 1969 estimates were all that were available for the other area counties. It was determined that the area source estimates in the 1969 inventory and in the above study did not include certain potentially significant emission categories. These were evaporative hydrocarbon losses from gasoline marketing, losses from solvent user sources like dry cleaners and decreasing operations; and evaporative losses from paints, thinners, etc. These additional losses were estimated using EPA estimation procedures and included in the inventory.(27)

Table 8-A summarizes the updated emission inventory resulting from the above mentioned efforts. Projections of future emissions are based on present regulations. Table 9-A is the inventory estimate that includes reductions attributable to the tighter point source controls proposed by the Texas Air Pollution Services Study, and application of the resulting tighter regulations to all sources in the Greater Houston Area. As can be seen, area sources are now a significant part of the total emission inventory. Additional regulations would be required to reduce them substantially. These could include solvent user regulations similar to those recommended in Appendix B of the August 14 issue of the Federal Register, and gasoline marketing evaporative emission controls.(2) Table 10-A is a summary of the emission inventory resulting from application of area source regulations like those just described.

Table 8-A. Projections of Total Hydrocarbons from Sources Other than Motor Vehicles(based on present regulations)

	1972	1975	1977	1978	1980
Point	360,000	206,400	214,100	219,100	229,000
Area	47,710	52,400	57,400	60,300	64,700
Transport	6,900	7,500	7,900	8,200	8,700
Total	413,610	266,300	279,400	287,600	302,400

Table 9-A. Projections of Total Hydrocarbons from Sources Other than Motor Vehicles Based on Possible Point Source Reductions from Revision to Regulation V

	1972	1975	1977	1978	1980
Point	360,000	160,385	68,253	69,600	71,500
Area	47,700	52,400	57,400	60,300	64,700
Transport	6,900	7,500	7,900	8,200	8,700
Total	414,600	220,285	133,553	138,100	144,900

Table 10-A. Projections of Total Hydrocarbons from Sources Other than Motor Vehicles Based on Regulation V Revision and Expansion to Include Evaporative Losses from Certain Area Sources

	1972	1975	1977	1978	1980
Point	360,000	160,385	68,253	69,600	71,500
Area	47,700	42,900	24,500	25,600	26,200
Transport	6,900	7,500	7,900	8,200	8,700
Total	414,600	210,785	100,653	103,400	105,900

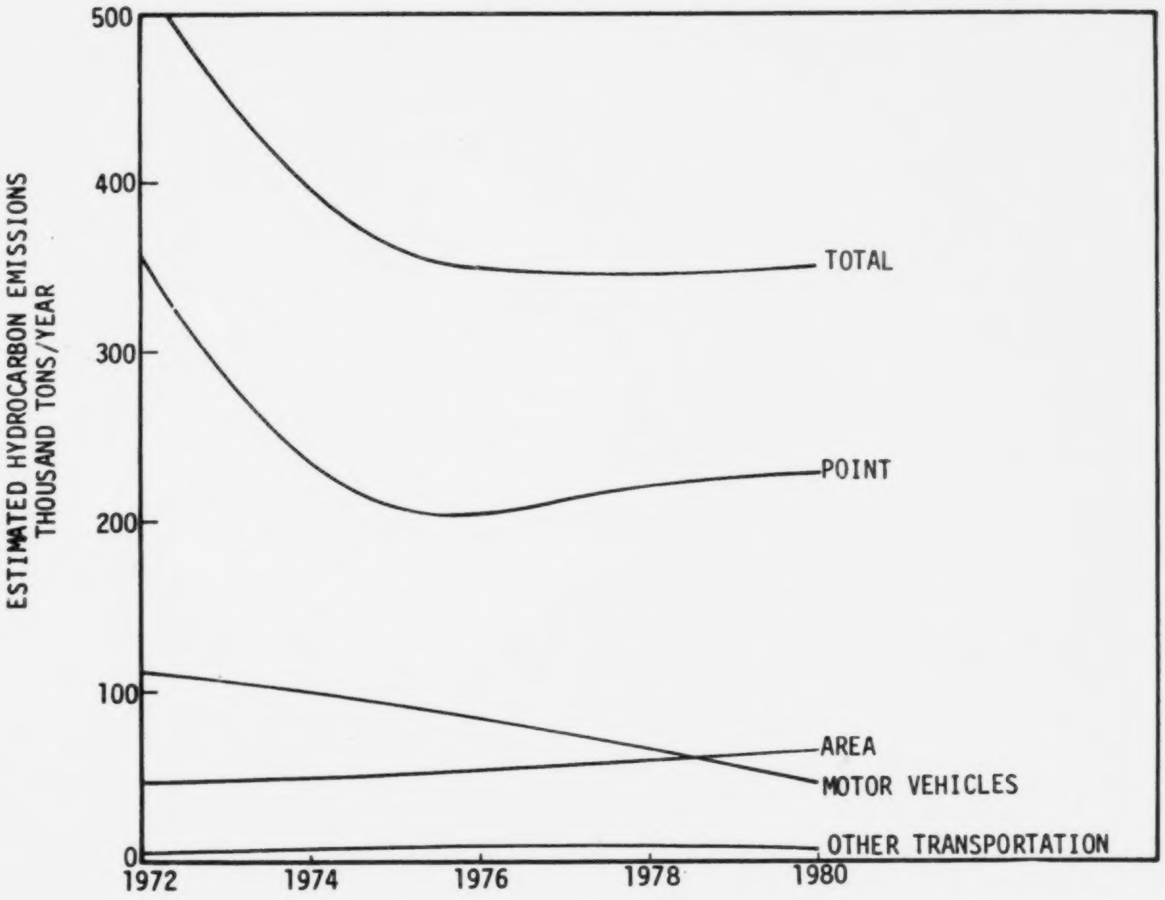

Figure 6-A. Estimated Hydrocarbon Emissions Based on Present Regulations

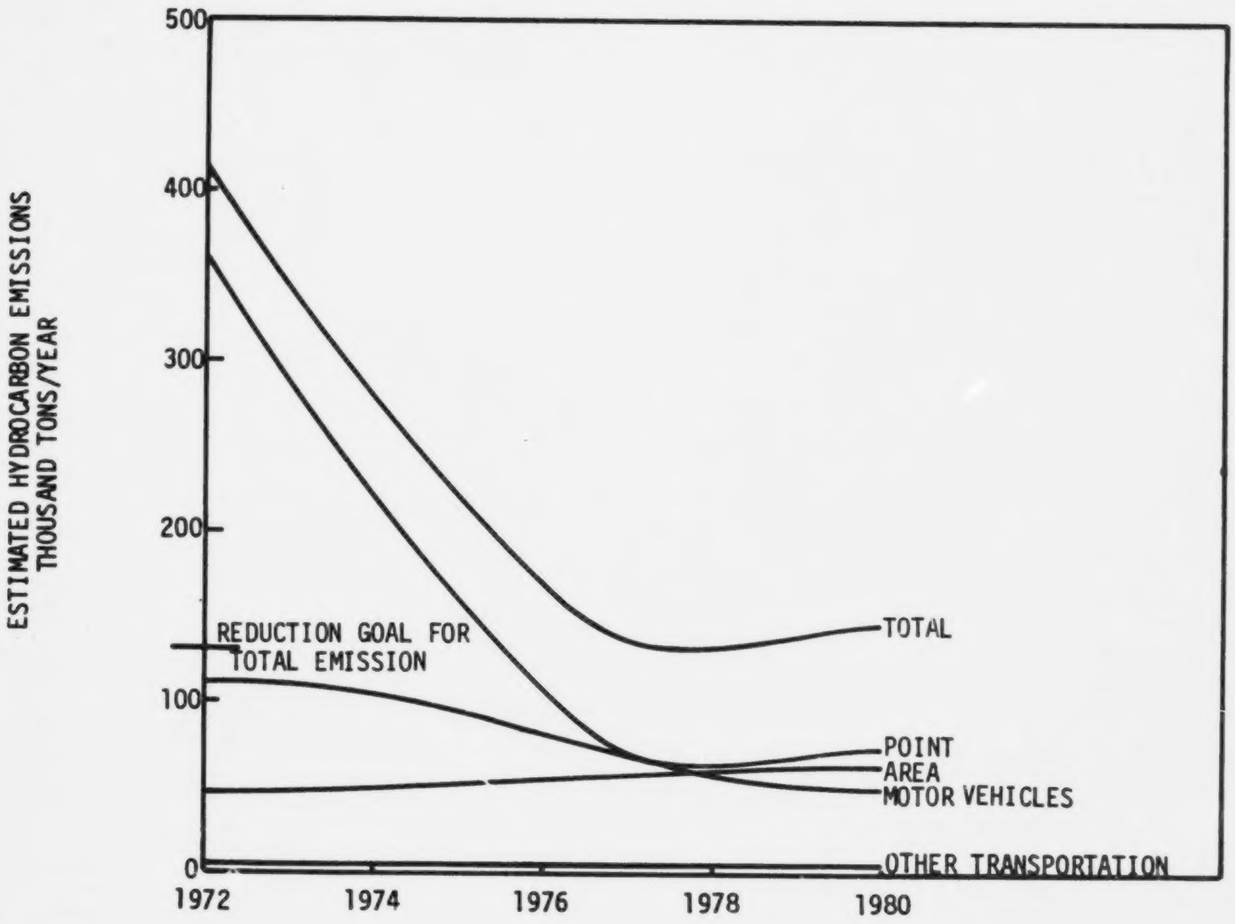

Figure 7-A. Estimated Hydrocarbon Emissions Considering Tightened Regulation V

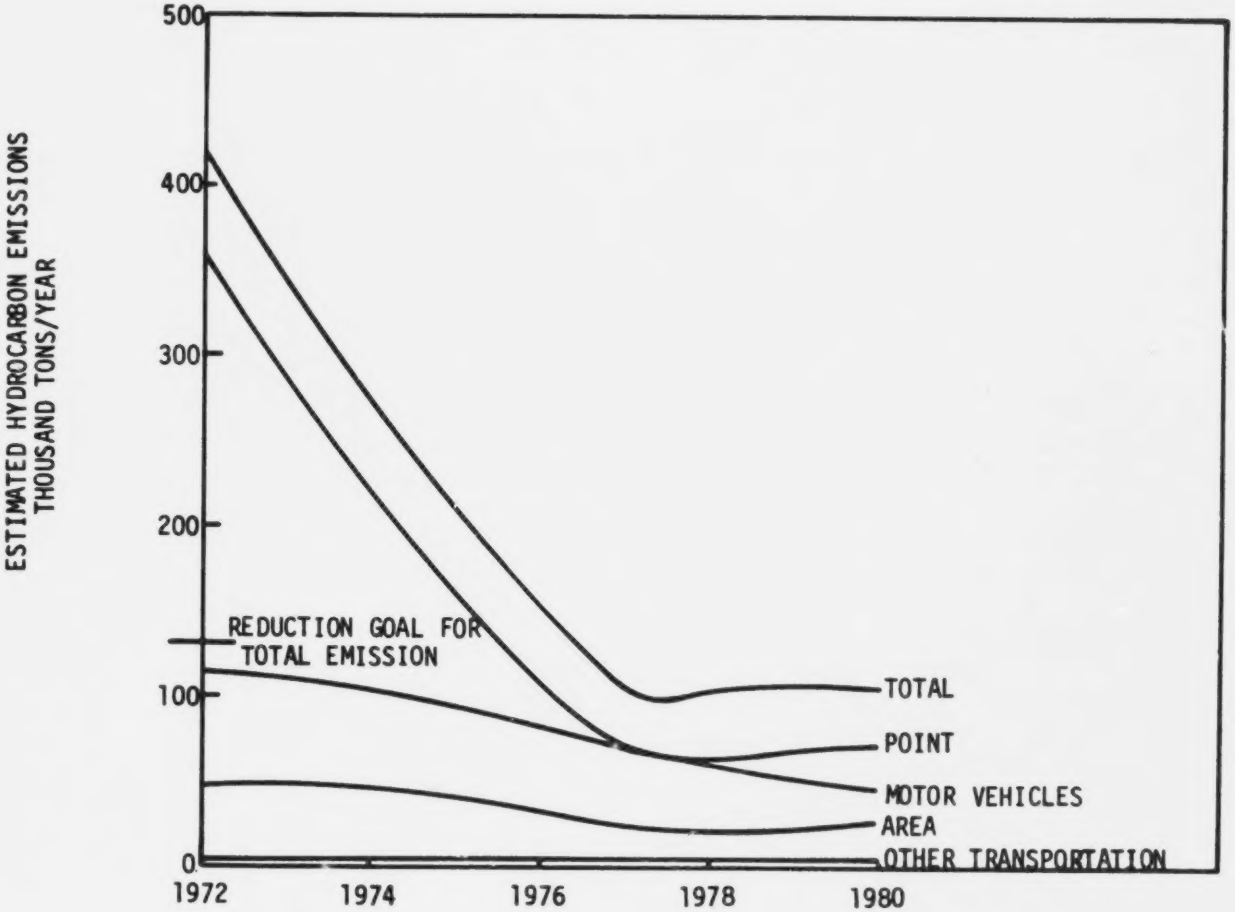

Figure 8-A. Estimated Hydrocarbon Emissions Considering Tightened Regulation V plus Evaporative Controls on Area Sources

A.3 MOTOR VEHICLE EMISSION DATA

Table 11-A presents the emission estimates for "Set II" pollutants from motor vehicles. The motor vehicle population and traffic data used to calculate the emissions are presented in Appendix B. The emission estimation procedure utilizes the latest EPA motor vehicle emission factors.(28) The computer model described in Appendix G was used for estimate calculations. The projections through 1980 assume Federal regulations for motor vehicle emission control will be met.

Table 12-A is the estimates of "Set II" emissions based on implementation of a vehicle inspection/maintenance program.

Table 13-A is the estimate of "Set II" emissions based on an inspection/maintenance program and a VSAD/LIAF retrofit of pre-1968 light duty vehicles.

Table 14-A is the estimate of "Set II" emissions based on an inspection/maintenance program, a VSAD/LIAF retrofit of pre-1968 light duty vehicles and a retrofit of catalytic converter to all 68 - 74 light duty vehicles.

Measures which reduce VMT also reduce emissions. Figure 9-A shows the relationship of VMT to emissions. Although the reductions are directly proportional, emissions never go to zero, even with 100% VMT reduction, because heavy duty vehicles are assumed to be unaffected by any transportation oriented strategy.

Table 11-A. Motor Vehicle Emission Projections Based on Federal Motor Vehicle Emission Controls

Source Category	1972	1975	1977	1978	1980
		Total Hydrocarbon Emissions			
Pre 1968 LDV	27,600	12,500	6,100	4,600	2,800
1968-74 LDV	28,000	37,900	30,700	24,400	14,900
Post 1974 LDV	0	200	2,500	4,300	8,100
HDV	9,700	11,600	11,100	10,800	10,400
Evap. & CC emissions	45,900	29,300	19,600	16,100	11,300
Total Motor Vehicle	111,300	91,500	70,000	60,200	47,500
		Total Carbon Monoxide Emissions			
Pre 1968 LDV	290,200	131,500	64,000	48,700	29,000
1968-74 LDV	307,000	379,000	302,100	235,400	137,400
Post 1974 LDV	0	1,300	17,700	30,600	56,500
HDV	65,900	75,700	71,300	68,700	65,100
Total Motor Vehicle	663,100	587,500	455,100	383,400	288,000
		Total Nitrogen Oxides Emissions			
Pre 1968 LDV	19,400	8,800	4,300	3,200	1,900
1968-74 LDV	41,100	60,400	48,600	39,500	23,500
Post 1974 LDV	0	1,600	10,400	11,800	14,300
HDV	6,200	8,200	9,300	9,800	10,600
Total Motor Vehicle	66,700	79,000	72,600	64,300	50,300

LDV = Light Duty Vehicles
HDV = Heavy Duty Vehicles
Evap & CC = Evaporative and crankcase

Table 12-A. Motor Vehicle Emission Projections Based on Federal Controls and Inspection/Maintenance Program

Source Category	1972	1975	1977	1978	1980
Total Hydrocarbon Emissions					
Pre 1968 LDV	27,600	11,000	5,400	4,100	2,400
1968-74 LDV	28,000	33,400	27,000	21,500	13,200
Post 1974 LDV	0	100	2,200	3,800	7,100
HDV	9,700	11,600	11,100	10,800	10,400
Evap. & CC emissions	46,000	29,300	19,600	16,100	11,300
Total Motor Vehicle	111,300	85,400	65,300	56,300	44,400
Total Carbon Monoxide Emissions					
Pre 1968 LDV	290,200	131,500	64,000	48,700	29,000
1968-74 LDV	307,000	379,000	302,100	235,500	137,400
Post 1974 LDV	0	1,300	17,700	30,600	56,500
HDV	65,900	75,700	71,300	68,700	65,100
Total Motor Vehicle	633,100	587,500	455,100	383,500	288,000
Total Nitrogen Oxides Emissions					
Pre 1968 LDV	19,400	7,900	3,800	2,900	1,700
1968-74 LDV	41,100	54,300	43,800	35,600	21,100
Post 1974 LDV	0	1,500	9,400	10,600	12,800
HDV	6,200	8,200	9,300	9,800	10,600
Total Motor Vehicle	66,700	71,900	66,300	58,900	46,200

LDV = Light Duty Vehicles
HDV = Heavy Duty Vehicles
Evap & CC = Evaporative and crankcase

Table 13-A. Motor Vehicle Emission Projections Based on Federal Controls, Inspection/Maintenance, and VSAL/LIAF Retrofit

Source Category	1972	1975	1977	1978	1980
		Total Hydrocarbon Emissions			
Pre 1968 LDV	27,600	9,400	4,600	3,500	2,100
1968-74 LDV	28,000	35,700	28,900	22,900	14,000
Post 1974 LDV	0	200	2,300	4,100	7,600
HDV	9,700	11,600	11,100	10,800	10,400
Evap. & CC emissions	46,000	29,300	19,600	16,100	11,300
Total Motor Vehicle	111,300	86,200	66,500	57,400	45,400
		Total Carbon Monoxide Emissions			
Pre 1968 LDV	290,200	101,300	49,200	37,500	22,300
1968-74 LDV	307,000	379,000	302,100	235,500	137,400
Post 1974 LDV	0	1,300	17,700	30,600	56,500
HDV	65,900	75,700	71,300	68,700	65,100
Total Motor Vehicle	663,100	557,300	440,300	372,300	281,300
		Total Nitrogen Oxides Emissions			
Pre 1968 LDV	19,400	8,000	3,900	3,000	1,800
1968-74 LDV	41,100	57,400	46,200	37,500	22,300
Post 1974 LDV	0	1,600	9,900	11,200	13,500
HDV	6,200	8,200	9,300	9,800	10,600
Total Motor Vehicle	66,700	75,200	69,300	61,500	48,200

LDV = Light Duty Vehicles
HDV = Heavy Duty Vehicles
Evap & CC = Evaporative and crankcase

Table 14-A. Motor Vehicle Emission Projections Based on Federal Controls, Inspection/Maintenance, VSAD and Catalytic Converter Retrofit

Source Category	1972	1975	1977	1978	1980
	Total Hydrocarbon Emissions				
Pre 1968 LDV	27,600	9,400	4,600	3,500	2,100
1968-74 LDV	28,000	19,000	15,400	12,200	7,500
Post 1974 LDV	0	200	2,300	4,100	7,600
HDV	9,700	11,600	11,100	10,800	10,400
Evap. & CC emissions	46,000	29,300	19,600	16,100	11,300
Total Motor Vehicle	111,300	69,500	53,000	46,700	38,900
	Total Carbon Monoxide Emissions				
Pre 1968 LDV	290,200	101,300	49,200	37,500	22,300
1968-74 LDV	307,000	379,000	302,100	235,500	137,400
Post 1974 LDV	0	1,300	17,700	30,600	56,500
HDV	65,900	75,700	71,300	68,700	65,100
Total Motor Vehicle	663,100	557,300	440,300	372,300	281,300
	Total Nitrogen Oxides Emissions				
Pre 1968 LDV	19,400	8,000	3,900	3,000	1,800
1968-74 LDV	41,100	30,200	24,300	19,800	11,700
Post 1974 LDV	0	1,600	9,900	11,200	13,500
HDV	6,200	8,200	9,300	9,800	10,600
Total Motor Vehicle	66,700	48,000	47,400	43,800	37,600

LDV = Light Duty Vehicles
HDV = Heavy Duty Vehicles
Evap & CC = Evaporative and crankcase

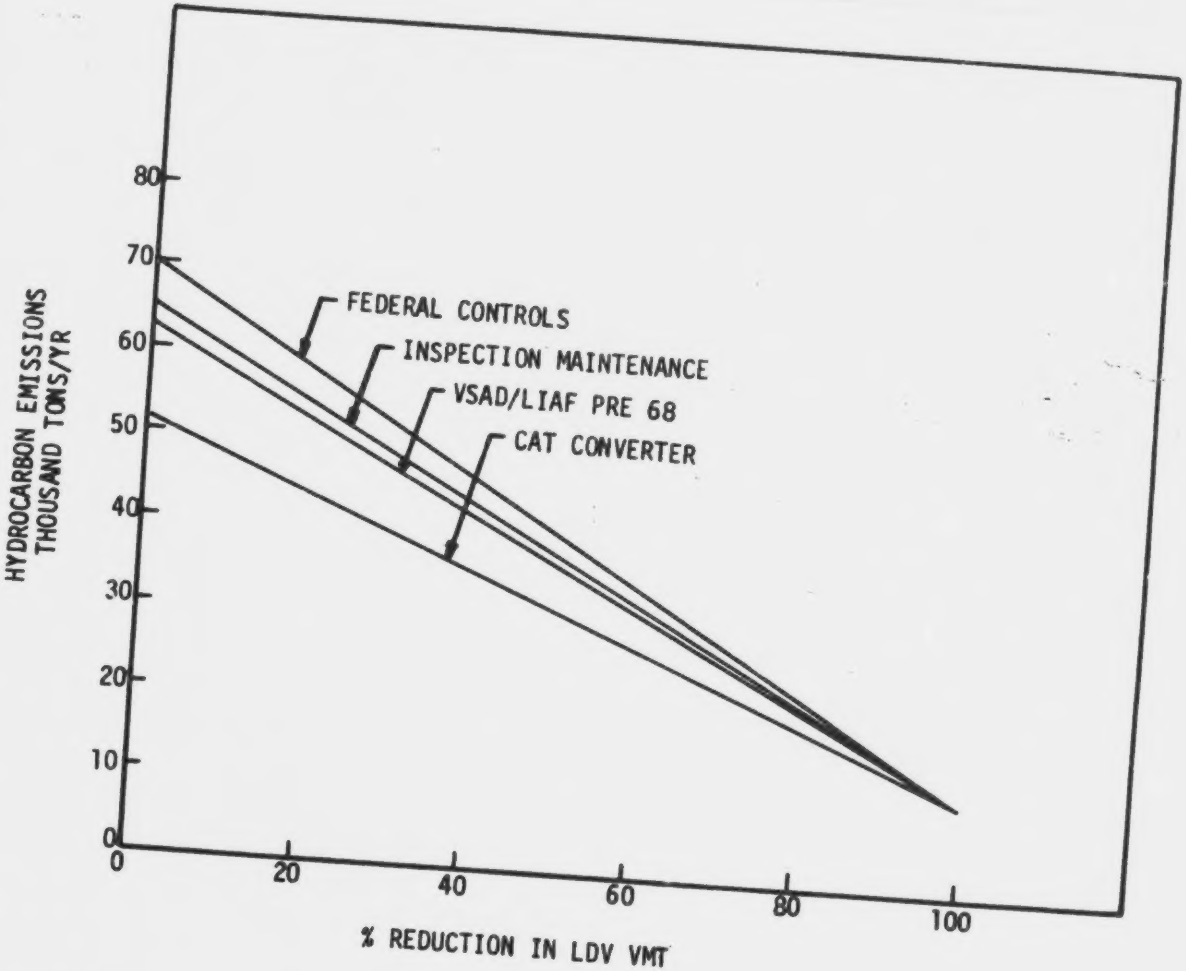

Figure 9-A Percent reduction in VMT vs. Hydrocarbon emissions

APPENDIX B
TRANSPORTATION DATA BASE

The Greater Houston Area has a heavily automobile oriented transportation environment. Some 96% of the total person trips in the area are made by private motor vehicles. Even in the most concentrated activity center in the region, the Houston CBD, only slightly over 12% of the person trips are by transit.(29)

Principal sources of transportation data in the area are the Houston-Galveston Regional Transportation Study (H-GRTS) and the Houston Transit Action Program. H-GRTS is a cooperative venture sponsored by the cities of Houston, Pasadena, Galveston, Baytown and Texas City; the eight counties of the Greater Houston Area and the Texas Highway Department. H-GRTS is responsible for continuing transportation planning functions in the region.

The Transit Action Program is a project to develop immediate and long range plans for public transit services in the Houston metropolitan area. The program is jointly funded by the Urban Mass Transportation Administration (UMTA) of the Federal Government's Department of Transportation and the City of Houston.

Travel Data - Motor vehicle travel in the eight county H-GRTS Area totalled some 13 billion vehicle miles in 1971, an average of 35 million vehicle miles of travel per day. To accumulate this total, each registered vehicle in the region (see Table B-3) drove an average of 27 miles per day or 9,850 miles per year in 1971, consuming an estimated 1.15 billion gallons of gasoline and diesel fuel.(30)

Table B-1 presents 1971 average daily vehicle travel in the H-GRTS region. Approximately 75% of the travel occurs in Harris County, the most urbanized portion of the region, where nearly 80% of the total population and vehicle registration is concentrated.

More than 35% of the region's travel occurs on freeways and expressways; nearly 40% of the travel in Harris County is on these limited access facilities.

Table B-1. 1971 Daily Motor Vehicle Travel

Total System			Freeways and Expressways Only			
Area	System Mileage (miles)	Dly Mtr Veh Trvl (000 mi)	Dly Mtr Fwy (000 mi)	Veh Trvl Expy (000 mi)	Total (000 mi)	% of Total Travel
Brazoria	1,765.1	1,887	-	82	82	4.3
Chambers	553.6	752	481	-	481	64.0
Fort Bend	1,230.9	1,252	29	-	29	2.4
Galveston	1,305.1	2.453	379	200	579	23.6
Harris	8,555.5	25,867	10,098	225	10,323	39.9
Liberty	945.5	797	-	86	86	1.1
Montgomery	1,645.6	1,553	562	269	831	53.5
Waller	749.6	448	121	12	133	29.7
Total H-GRTS	16,750.9	35,009	11,670	874	12,544	35.8

On the basis of Greater Houston Area traffic volume historical data, the recent annual traffic growth rate appears to be approximately 6.5% per year.(31) With compounding, this annual rate increase produces a growth factor of 1.46 from 1971 to 1977.

No reliable data on vehicle miles of travel by vehicle type is available for the Houston-Galveston Area. Typically, heavy vehicles account for 5 to 6% of total vehicle travel in a large urban area.

Applying the 6% figure for heavy vehicle travel and the 1.46% growth factor to the 1971 vehicle travel figures indicated in Table B-1, 1977 vehicle travel projections and breakdowns by vehicle type of the 1971 figures were developed. These estimates are presented in Table B-2 and projected to 1980 in Figure B-1.

Table B-2. Daily Vehicle Miles of Travel (thousands)

	1971		1977	
Area	Light Vehicles	Heavy Vehicles	Light Vehicles	Heavy Vehicles
Brazoria	1,774	113	2,590	165
Chambers	707	45	1,025	66
Fort Bend	1,177	75	1,718	109
Galveston	2,306	147	3,370	214
Harris	24,146	1,541	35,720	2,280
Liberty	749	48	1,093	70
Montgomery	1,460	93	2,130	136
Waller	421	27	615	39
Total H-GRTS	32,909	2,100	48,000	3,060

No attempt has been made to segregate vehicle miles traveled by trip purpose, as the control measures contemplated do not distinguish between trip types on a regional aggregate basis.

Vehicle Population Data - Table B-3 presents 1970 and 1971 vehicle registration totals for the H-GRTS area. Nearly 90% of the automobiles and over 80% of the region's total motor vehicle population are concentrated in Harris County. If the recent growth rates for total vehicles and automobiles, 7.7 and 6.3 respectively, were to continue to 1977, some 2,100,000 total motor vehicles and some 1,420,000 automobiles would be registered in the region by 1977.

Table B-3. Motor Vehicle Registration - H-GRTS Area

County	All Vehicles 1970	All Vehicles 1971	All Vehicles % Increase	Automobiles 1970	Automobiles 1971	Automobiles % Increase
Brazoria	73,261	77,881	6.3	46,635	48,798	4.6
Chambers	11,380	12,342	8.5	5,643	6,157	9.1
Fort Bend	31,262	34,072	9.0	19,830	21,498	8.4
Galveston	101,193	106,908	5.6	72,725	75,843	4.3
Harris	1,124,845	1,211,109	7.7	831,677	884,548	6.4
Liberty	23,560	25,422	7.9	13,292	13,962	5.0
Montgomery	33,250	38,314	15.2	19,393	21,837	12.6
Waller	9,133	10,397	13.8	5,350	6,194	15.8
H-GRTS Area	1,407,884	1,516,445	7.7	1,014,545	1,078,837	6.3

Local data on automobiles in fleet usage was not acquired. In large urban areas such as Houston-Galveston, fleet vehicles normally comprise 5 to 7% of total auto registration. Table B-4 presents a breakdown of utilization of automobiles maintained in fleets of 10 or more based on national figures.(32)

Table B-4. Fleet Vehicle Usage - Automobiles

Type Fleet	Percent Total Fleet Autos
Business	65.00
Government	12.35
Utilities	8.40
Police	3.98
Taxi	3.52
Rental	6.19
Driver Training	0.56

Travel by Vehicle Age - Estimates of total daily vehicle miles of travel by vehicle age groups for the years 1971 and 1977, segregated for light and heavy vehicles are presented in Tables B-5 through B-13.

Separate compilations for the H-GRTS Area, for Harris County, which comprises 75% of the H-GRTS total and for Galveston County, which accounts for an additional 7%, are presented.

Table B-5. 1971 Daily Vehicle Mile Totals
H-GRTS Area - Light Vehicles

Age	(1) Fraction of Vehicles in Use	(2) Relative Annual Mileage Driven	(3) Weighted Per Cent of Daily Travel	Daily VMT (thousands)
0	8.80	3.8	4.20	1,382
1	12.30	7.5	11.57	3,808
2	12.30	11.4	17.59	5,788
3	11.70	10.4	15.27	5,025
4	9.90	9.5	11.80	3,883
5	9.70	8.5	10.34	3,403
6	9.10	7.8	8.91	2,932
7	7.20	7.1	6.40	2,106
8	5.80	6.4	4.66	1,534
9	4.40	5.9	3.26	1,073
10	2.40	5.5	1.66	546
11	1.90	5.4	1.29	425
12	1.00	5.4	.68	224
Over 12	3.50	5.4	2.37	780
	100.00	100.00	100.00	32,909

$$3 = \frac{(1) \times (2)}{\Sigma (1) \times (2)}$$

Table B-6. 1977 Daily Vehicle Mile Totals
H-GRTS Area - Light Vehicles

Age	(1) Fraction of Vehicles in Use	(2) Relative Annual Mileage Driven	(3) Weighted Per Cent of Daily Travel	Daily VMT (thousands)
0	8.80	3.8	4.19	2,011
1	12.30	7.5	11.55	5,544
2	12.30	11.4	17.55	8,424
3	11.70	10.4	15.23	7,310
4	10.40	9.5	12.37	5,938
5	9.70	8.5	10.30	4,944
6	9.10	7.8	8.88	4.263
7	7.20	7.1	6.40	3.072
8	5.70	6.4	4.54	2,194
9	4.30	5.9	3.18	1,526
10	2.30	5.5	1.58	758
11	1.80	5.4	1.22	586
12	1.00	5.4	0.68	326
Over 12	3.40	5.4	2.30	1,104
	100.00	100.00	100.00	48,000

$$3 = \frac{(1) \times (2)}{\Sigma (1) \times (2)}$$

Table B-7. 1971 and 1977 Daily VMT
H-GRTS Area - Heavy Vehicles

Age	(1) Fraction of Vehicles in Use	(2) Relative Annual Mileage Driven	(3) Weighted Per Cent of Daily Travel	1971 Daily VMT (thousands)	1977 Daily VMT (thousands)
0	.034	3.6	.016	25	36
1	.071	7.6	.074	114	168
2	.100	11.6	.156	240	356
3	.095	10.9	.140	216	319
4	.088	10.2	.121	186	276
5	.080	9.4	.102	157	233
6	.070	8.5	.081	125	185
7	.062	7.7	.064	99	146
8	.053	6.9	.049	76	112
9	.038	6.2	.032	49	73
10	.037	5.3	.026	40	59
11	.033	4.6	.021	32	48
12	.032	3.8	.016	25	36
Over 12	.207	3.7	.102	157	233
	1.000	100.0	1.000	1,541	2,280

$$3 = \frac{(1) \times (2)}{\sum (1) \times (2)}$$

Table B-8. 1971 Daily Vehicle Mile Totals
Harris County - Light Vehicles

Age	(1) Fraction of Vehicles in Use	(2) Relative Annual Mileage Driven	(3) Weighted Per Cent of Daily Travel	Daily VMT (thousands)
0	9.23	3.8	4.40	1,062
1	12.49	7.5	11.76	2,840
2	12.43	11.4	17.79	4,296
3	11.72	10.4	15.30	3,694
4	9.85	9.5	11.75	2,837
5	9.59	8.5	10.23	2,470
6	9.07	7.8	8.88	2,144
7	7.10	7.1	6.33	1,528
8	5.75	6.4	4.62	1,116
9	4.24	5.9	3.13	756
10	2.30	5.5	1.58	382
11	1.80	5.4	1.22	295
12	1.04	5.4	.71	171
Over 12	3.39	5.4	2.30	555
	100.00	100.00	100.00	24,146

$$3 = \frac{(1) \times (2)}{\Sigma (1) \times (2)}$$

Table B-9. 1977 Daily Vehicle Mile Totals
Harris County - Light Vehicles

Age	(1) Fraction of Vehicles in Use	(2) Relative Annual mileage Driven	(3) Weighted Per Cent of Daily Travel	Daily VMT (thousands)
0	9.20	3.8	4.38	1,565
1	11.70	7.5	11.0	3,929
2	12.40	11.4	17.72	6,330
3	11.70	10.4	15.25	5,446
4	10.70	9.5	12.74	4,551
5	9.90	8.5	10.55	3,768
6	8.50	7.8	8.31	2,968
7	7.10	7.1	6.32	2,258
8	5.60	6.4	4.49	1,604
9	4.20	5.9	3.11	1,111
10	2.90	5.5	2.00	714
11	1.70	5.4	1.15	411
12	1.00	5.4	.68	243
Over 12	3.40	5.4	2.30	822
	100.00	100.00	100.00	35,720

$$3 = \frac{(1) \times (2)}{\Sigma (1) \times (2)}$$

Table B-10. 1971 and 1977 Daily VMT
Harris County - Heavy Vehicles

Age	(1) Fraction of Vehicles in Use	(2) Relative Annual Mileage Driven	(3) Weighted Per Cent of Daily Travel	1971 Daily VMT (thousands)	1977 Daily VMT (thousands)
0	.034	3.6	.016	25	36
1	.071	7.6	.074	114	168
2	.100	11.6	.156	240	356
3	.095	10.9	.140	216	319
4	.088	10.2	.121	186	276
5	.080	9.4	.102	157	233
6	.070	8.5	.081	125	185
7	.062	7.7	.064	99	146
8	.053	6.9	.049	76	112
9	.038	6.2	.032	49	73
10	.037	5.3	.026	40	59
11	.033	4.6	.021	32	48
12	.032	3.8	.016	25	36
Over 12	.207	3.7	.102	157	233
	1.000	100.0	1.000	1,541	2,280

$$3 = \frac{(1) \times (2)}{\Sigma\ (1) \times (2)}$$

Table B-11. 1971 Daily Vehicle Mile Totals
Galveston County - Light Vehicles

Age	(1) Fraction of Vehicles in Use	(2) Relative Annual Mileage Driven	(3) Weighted Per Cent of Daily Travel	Daily VMT (thousands)
0	7.34	3.8	3.50	81
1	11.53	7.5	10.87	251
2	11.59	11.4	16.59	383
3	11.28	10.4	14.74	340
4	10.00	9.5	11.93	275
5	10.28	8.5	10.97	253
6	9.72	7.8	9.52	220
7	9.56	7.1	6.74	155
8	6.10	6.4	4.90	113
9	4.89	5.9	3.62	83
10	2.62	5.5	1.81	42
11	2.18	5.4	1.48	34
12	1.09	5.4	.74	17
Over 12	3.82	5.4	2.59	60
	100.00	100.00	100.00	2,306

$$3 = \frac{(1) \times (2)}{\sum (1) \times (2)}$$

Table B-12. 1977 Daily Vehicle Mile Totals Galveston County - Light Vehicles

Age	(1) Fraction of Vehicles in Use	(2) Relative Annual Mileage Driven	(3) Weighted Per Cent of Daily Travel	Daily VMT (thousands)
0	7.3	3.8	3.47	117
1	11.50	7.5	10.78	363
2	12.00	11.4	17.10	577
3	11.60	10.4	15.08	509
4	11.00	9.5	13.07	440
5	9.80	8.5	10.42	351
6	8.50	7.8	8.29	279
7	7.50	7.1	6.66	224
8	6.10	6.4	4.88	164
9	4.50	5.9	3.32	112
10	3.20	5.5	2.20	74
11	2.10	5.4	1.42	48
12	1.10	5.4	.74	25
Over 12	3.80	5.4	2.57	87
	100.00	100.00	100.00	3,370

$$3 = \frac{(1) \times (2)}{\sum (1) \times (2)}$$

Table B-13. 1971 and 1977 Daily VMT
Galveston County - Heavy Vehicles

Age	(1) Fraction of Vehicles in Use	(2) Relative Annual Mileage Driven	(3) Weighted Per Cent of Daily Travel	1971 Daily VMT (thousands)	1977 Daily VMT (thousands)
0	.034	3.6	.016	2	3
1	.071	7.6	.074	11	16
2	.100	11.6	.156	23	33
3	.095	10.9	.140	21	30
4	.088	10.2	.121	18	26
5	.080	9.4	.102	15	22
6	.070	8.5	.081	12	17
7	.062	7.7	.064	9	14
8	.053	6.9	.049	7	11
9	.038	6.2	.032	5	7
10	.037	5.3	.026	4	6
11	.033	4.6	.021	3	4
12	.032	3.8	.016	2	3
Over 12	.207	3.7	.102	15	22
		100.00	1.00	147	214

$$3 = \frac{(1) \times (2)}{\Sigma (1) \times (2)}$$

For light vehicles, the 1971 fractions of the vehicle population by age group were determined from current registration statistics.(33) Vehicle population age composition varies slightly between Harris County, Galveston County and the H-GRTS Area as a whole. For 1977 auto population distributions, the current age distributions were adjusted to eliminate variations due to past unpopular model years which could not logically be projected to reoccur in future model year productions.

For heavy vehicles, vehicle age distributions are based on national figures. Relative annual mileage by vehicle age figures for both light and heavy vehicles are based on national statistics.(28) Vehicle mile totals as apportioned in these tables are based on the figures presented in Table B-2.

As can be seen from the tables, one-third of the daily vehicle miles traveled in 1977 by light vehicles will be accounted for by vehicles meeting the 1975 Federal emission standards. Less than 6% of the 1977 daily vehicle miles will be contributed by pre-control (pre-1968 model) vehicles. Vehicles of 1968 and 1969 model years will account for roughly 8% of the 1977 daily vehicle mile total in the region.

Travel Speed Data - Distributions of vehicle miles traveled by speed ranges for the region are not available from recent survey data nor are complete figures for vehicle miles of travel by functional street classification. However, the regional transportation study estimates that in the urban areas, 80% of the vehicle miles traveled are on freeways, expressways and arterial surface streets. Collector and local streets each carry about 10% of total vehicle miles traveled. In rural areas 65% of the travel is on freeways, expressways and surface arterials; 25% on collectors and 10% on local streets.(35) The above information, together with assumed average speeds* by functional street classification enables estimation of the overall average travel speeds indicated on Table B-14.

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*Freeways and Expressways 50 MPH, Surface Arterials 30 MPH, Collector and Locals 20 MPH

Table B-14. Average Travel Speed by County

County	Total Daily VMT	Freeway & Expressway Percent of Total	Average Travel Speed (MPH)
Brazoria	1,887,000	4.3	28.5
Chambers	752,000	64.0	44.7
Fort Bend	1,252,000	2.4	28.4
Galveston	2,453,000	23.6	32.8
Harris	25,867,000	39.9	36.1
Liberty	797,000	1.1	36.5
Montgomery	1,553,000	53.5	38.1
Waller	448,000	29.7	40.3

The figures, particularly those for Harris County which accounts for 80% of the total travel, indicate excellent levels of traffic service for a major urban area. These high levels of service are substantiated by speed studies on radial freeways serving the Houston CBD presented on Table B-15.(36)

Table B-15. Average Speed on Radial Freeways

Facility	Inside Loop	Loop to Belt	Outside Belt	Total Average
East Fwy (I-10)	52.0 (51.6)	57.0 (56.3)	63.1 (63.1)	59.2 (59.0)
Eastex Fwy (US-59)	49.4 (43.2)	54.0 (53.8)	61.4 (61.0)	54.4 (52.2)
Gulf Fwy (I-45	47.0 (22.2)	58.1 (54.3)	62.0 (63.4)	53.6 (35.6)
Katy Fwy (I-10)	53.9 (54.6)	54.5 (37.3)	64.0 (64.3)	59.8 (53.0)
North Fwy (I-45)	51.0 (36.5)	56.8 (52.0)	63.1 (63.1)	58.6 (53.0)
South W (US-59)	49.3 (31.8)	55.3 (50.3)	- -	52.4 (40.2)
LaPorte Fwy (SH-225)	- -	53.2 (53.8)	- -	53.2 (53.8)
Avg. All Radial Freeways	50.2 (35.6)	55.7 (50.3)	63.2 (63.3)	56.8 (49.4)

0.00 = Off Peak Speed in MPH, Non Directional
(0.00) = PM Peak Speed in Outbound Direction

The inference of these relatively high average speeds is that major emission reductions cannot be anticipated as a result of traffic flow improvements. To be sure, there are locations where flow improvements can be achieved and are being achieved through continuing programs. However, the percentage of operations below 20 miles per hour, the high leverage area for achieving pollution reductions through flow improvements, is quite small and of the operations in this range, many are on local streets where speed increases are undesirable.

Houston and Galveston CBDs - Modifications to Central Business District travel figure prominently among transportation control strategies which have been identified as having promise in the Seven Cities Study. For this reason it is instructive to document travel data for the Houston CBD.

Table B-16 presents 1971 statistics for travel to and from the Houston CBD and contrasts this data with surveys taken in earlier years.(29) Note that the comparison to earlier surveys is on the basis of a smaller area, the Houston Central District (CTD) as it was defined in 1953.

The most salient feature of the above data is that since 1965, traffic entering the old central district has increased by only 4.2%. Only some 13.5% of those entering the CTD use transit and this percentage has been steadily dropping over time.

The 1971 cordon counts indicated a total of 300,213 passenger cars (including taxis) crossing the CTD cordon - 79.1% of the total crossings and 79,147 or 20.9% commercial vehicles. These breakdowns are deceptive as the commercial vehicle count includes non-commercially registered

Table B-16. Person and Vehicle Movement Trends in Central Houston
(Between 7:00 AM and 6:00 PM)

	CBD	1953 CTD Definition			
	1971	1971	1965	1960	1953
Vehicle crossings	477,690	379,360	363,927	327,875	340,658
Person crossings	771,127	633,796	641,709	531,004	639,964
Bus passenger crossings	96,713	85,707	107,083	109,551	152,491
Bus passenger % total	12.5	13.5	16.6	20.6	23.8
Max. vehicle accumulation and time of day	45,477 11:30-12 AM	29,752 2:00-2:30 PM	33,421 2:30-3:00 PM	24,869 1:00-1:30 PM	22,735 11:30-12:00 AM
Max. person accumulation and time of day	67,265 11:30-12 AM	54,908 2:00-2:30 PM	59,809 1:30-2:00 PM	51,596 1:30-2:00 PM	55,229 11:30-12:00 AM

pickup and panel trucks which are actually used for personal transportation. The 1965 classification count which included non-commercially registered pickups and panels in the passenger vehicle category indicated 94% passenger vehicles, 6% commercial vehicles, and these earlier percentages are estimated to reasonably indicate the actual current situation.

Based on traffic volume variation studies, it is estimated that the 11-hour daytime counts summarized in Table B-16 account for 80% of the total daily travel entering and leaving the CBD. Peak hour cordon crossings; 48,369 between 7 and 8 A.M., and 51,517 between 4:30 and 5:30 P.M., account for 26.5% of the total 11-hour daytime period crossings.

Average vehicle occupancy at the cordon was 1.38 (exclusing transit passengers) but dipped below 1.3 during the morning commuter period.(37)

The Texas Highway Department provided trip length information by trip purpose and trip purpose breakdowns for travel to the Houston CBD. This information, together with total 24-hour CBD travel as estimated from the 11-hour counts was utilized to develop Table B-17.

As indicated in the table, travel to, from and within the Houston CBD accounts for less than 7.4% of the light vehicle miles traveled in the H-GRTS region and some 10% of Harris County light vehicle miles traveled. Houston CBD oriented travel accounts for some 3.6% of the heavy vehicle miles traveled in the region and less than 4.9% of the Harris County heavy vehicle VMT.

Cordon studies of the Galveston CBD(29) indicated a total of 90,172 vehicle and 149,986 person crossings of the cordon. By comparison, this is less than 19% of the travel activity associated with the Houston CBD

Table B-17. 1971 CBD - Regional VMT Relationships

Trip Purpose	Average Trip Length (miles)	% CBD Trips	Number Trips (24 Hrs.)	VMT	% HGRTS VMT		% Harris Co. VMT	
					Lt. Veh.	Hvy. Veh.	Lt. Veh.	Hvy. Veh.
Home Based Work	7.4	49.7	211,623	1,566,000	4.76		6.48	
Home Based Other	4.7	30.3	129,017	606,000	1.84		2.51	
Non-Home Based-Passenger	4.2	14	59,612	250,000	.76		1.04	
Non-Home Based-Commercial	4.2	6	17,887	75,000		3.57		4.87
Total		100	425,800	2,797,000	7.38	3.57	10.03	4.87

and since Galveston CBD oriented travel constitutes such an insignificant percentage of regional travel, detail breakdowns of it have not been explored.

Surveys(18) of companies employing 45% of the Houston CBD's work force of 110,000 indicate a high percentage, between 27 and 32%, ride to work in car pools. (This includes riding with spouse.) However, very few CBD employers have attempted to encourage car-pooling. The surveys also indicated a considerable staggering of P.M. work quitting times but strong concentration of morning starting times at 8 A.M. as indicated on Table B-18.

Table B-18. Distribution of Houston CBD Work Start and Quitting Hours

Start (AM)	Percent	Quit (PM)	Percent
7:00	1.75	4:00	.75
7:15		4:15	10.25
7:30	11.25	4:30	15.75
7:45	8.25	4:45	17.75
8:00	53.25	5:00	35.25
8:15	1.75	5:15	2.0
8:30	9.0	5:30	6.25
8:45	1.0	5:45	
9:00	1.75	6:00	1.25
9:15	2.0	6:15	.75
9:30	.75	6:30	.25
9:45		6:45	
10:00	.50	7:00	.75
	91.25		91.0

Central Business District Parking - Table B-19 presents off-street parking space inventories for the Houston and Galveston CBDs. When CBD vehicle accumulations, as presented in Table B-16 and which include vehicles traveling on city streets within the cordon as well as parked vehicles, are compared to parking space availability, and considering that on-street parking spaces are not included in the inventory, it becomes apparent that substantial reductions in spaces available would be necessary for parking limitation strategies to have significant impact on vehicle travel to the CBD.

Table B-19. CBD Off-Street Parking

Type	Houston CBD, 1972	Galveston CBD
Lot, Public	20,177	2190
Lot, Private	6,116	
Garage, Public	15,849	380
Garage, Private	4,582	
Customer Parking	1,692	
Total	48,416	2570

Transit - Local public transit services in the Houston region consist entirely of conventional bus operations. Although services are provided by several operators, 75% of the region's population and 98% of the region's transit passengers are served by Rapid Transit Lines, Inc. (RTL), a division of Houston City Lines, Inc., which is a subsidiary of National City Lines, Inc. Rapid Transit Lines, Inc. currently operate 735 route miles over 30 routes. All but 5 routes are radial trunk line routes to and/or through the Houston CBD. Average system operating speed is 12.94 miles per hour, 5 to 15% faster than averages in most major U.S. urban areas. This indicates both the efficiency of the transit operation and the high level of traffic service afforded by the areas street and highway network. The RTL operation involves a fleet of 381 buses with a total seating capacity of 19,429 passengers. Basic fare is 45 cents with 5 cent zonal fare increments and free transfers.(38)

Total transit ridership is nearly 80,000 passengers daily including school and CBD shuttle trips. Note that the transit passenger counts indicated in the CBD cordon data presented in Table B-16, 96,700 passengers, reflects double counting of passengers whose trips pass through the CBD.

The CBD accounts for 45% of all transit trip origins and destinations An additional 15% are concentrated in the Houston Medical Center - Rice Institute - University of Houston complexes south of the CBD. Some 84% of the transit patrons are captive riders.(39)

APPENDIX C

STUDY CONTACTS

This program began with a public meeting in Houston on September 19, 1972 to acquaint interested persons in the purpose and aims of the study, and to request those having data to come forward with it. As a result of this meeting, many follow-up visits and telephone conversations by TRW and DeLeuw, Cather and Company personnel; a "best available" body of data was assembled. A summary list of the agencies and persons contacted starts on page C-2. The largest portion of the data base came from the following sources.

- Air quality data was provided by Mr. Victor Howard, Director of the Pollution Control Division of the Houston Department of Public Health, and by the Texas Air Pollution Control Services through the Vehicle Emissions Committee chaired by Mr. Jim Kamrath.

- Mr. W. J. Laughlin of the Houston Transit Action Program provided most of the background information, conclusions, and findings of the Transit Action Program's recent system study.

- Mr. Oliver Stork, Urban Planning Engineer with the Texas Highway Department, and Study Director for H-GRTS, provided numerous reports and other data on current and projected vehicle travel, existing street and highway system, and ongoing and programmed improvements. This data constitutes the principal background for Appendix B and other analyses contained herein.

- The official point of contact with the Texas Air Pollution Control Services (and all other state agencies) was the Vehicle Emissions Committee whose full time members include Mr. H. Sievers; Mr. F. Hartman; and Chairman, Mr. J. Kamrath. Contacts with the Vehicle Emissions Committee were closely maintained, allowing for continuous interchange of data and ideas.

CONTACT SUMMARY CHART

Houston/Galveston

Agency/Person

Citizens'Environmental Coalition of Southeast Texas
Richard Sievers, Ph.D.

Galveston County Mainland Cities Health Department
Charles Poirier

Southwest Center for Urban Research
Harry Penson

League of Women Voters of Houston
Mrs. Janet Walker

Houston City Health Department
Albert G. Randall, M.D.
Victor Howard

Harris County Air/Water Pollution Control Department
Robert Douglas III

Harris County Commissioners Court
Judge Bill Elliott

Texas Railroad Commission
Frank Youngblood

San Jacinto TB & RD Association
W. R. Moore

Texas Air Control Board
Dr. Herbert McKee, Chairman
Charles Barden, Executive Secretary

Texas Transportation Institute
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Texas Division of Planning Coordination (Governor's office)
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Houston-Galveston Area Council
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Fred Brison

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Glenn MacCartel

Independent Garagemen's Assn.
Raymond Saunders

Houston Chamber of Commerce
Transportation Planning Committee
Joyce Kaye

APPENDIX D

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APPENDIX E

PUBLIC ATTITUDE SURVEY ON AUTO AIR POLLUTION IN THE GREATER HOUSTON AREA

Presented on the pages which follow are results of a questionaire distributed to a small sample of households in the Greater Houston Area. The survey was conducted with the assistance of a professional market research group which maintains standing panels of households in major metropolitan areas of the U. S., each panel representing a broad cross section of households in the given area. The following table indicates some characteristics of the households surveyed.

	Less than $4000	$4000-8000	$8000-10,000	$10,000-15,000	$15,000+	Total
No. Households having income	12	17	27	64	43	163

	0 Car	1-Car	2 Cars	3+ Cars	Total
No. Households having auto ownership	2	40	97	21	160

Significant insights from the survey are as follows:

- More than 93% of the respondents feel that air pollution is a problem in the Houston area and 76% feel it is a serious or very serious problem. Ninety-nine percent of the respondents feel air pollution is a problem nationwide and 84% feel it is a serious or very serious problem. The inference is that Houston area residents generally believe they have an air pollution problem but perceive their local problem as being less severe than that of the nation as a whole. (see question 10)

- Houston area residents generally support a retrofit program for pre-1975 vehicles if the cost is relatively low. Some 71% indicated they would favor a retrofit program costing about $50 and another 9% indicated they would not have strong objection to it. If the retrofit to pre-1975 vehicles were to cost $200, only some 35% would support it. The inference is that the public feels that a retrofit program for pre-1975 vehicles is reasonable but not a costly one such as a catalytic converter retrofit.

- Some 82% of the respondents favor an inspection/maintenance program. Another 10% indicate they are not strongly opposed to such a program. The respondents identified a charge of nearly $5.50 as a reasonable cost for the annual inspection, significantly above the actual estimated cost in the inspection program under consideration. Some 42% of the respondents felt the inspection should be done at state-operated inspection centers. Nearly 46% favored private garages and service stations and less than 10% favored city operated stations.

- Reaction to all types of travel restrictive controls is strongly negative. Among the restrictive controls, exclusive bus and car pool lanes followed by CBD traffic and parking bans were seen as more acceptible. The acceptability of exclusive lanes is attributed to the fact that this control is perceived as having minimum negative impact on the individual's current options; while acceptance of the "CBD restrictions" probably stems from the fact that only a small percentage of the area's residents must now drive there frequently. Strategies most unacceptible are those which affect all auto owners - gas rationing and high registration fees.

- Response to transit related questions generally indicates the area's current low reliance on public transit. Reasons given as most important for choice of auto travel are: "auto more flexible," indicating general reluctance to be tied to a transit schedule and possible dissatisfaction with current headways; "auto more available," indicating transit routes do not well serve origin-destination pairs for non CBD trips; and "auto faster." Factors seen as most important in encouraging utilization of public transit are "more frequent service," "conveniently located stops and stations" (better route coverage), "faster travel," and "lower fares." The responses indicate that achievement of significantly higher levels of utilization require major improvements in level of service (more routes, lower headways, faster operations) rather than cosmetic improvements such as cleaner buses, air conditioning, bus stop benches, shelters and the like.

- Some 37% of the respondents indicated interest in car pooling for work commute trips. An additional 9.5% car pool currently. However, 70% of the respondents indicated it would be difficult to organize or join an established car pool.

- Some 71% of the respondents favor staggered work hours as a means of reducing congestion. Only some 18% oppose it.

- Only 7.5% of the respondents would consider disposal of a family car if better public transit service were available. Another 19% indicate they might consider disposing of a car.

1. All autos made in 1975 and thereafter will be equipped with emmision control devices to reduce air pollution. If in 1975 you owned a car built before that year, how would you feel about a law requiring you to put emission control equipment which might cost $200 on your car? ("X" BELOW)

2. How would you feel about this law if the cost was reduced by government subsidy to about $50? ("X" BELOW)

Feeling Toward Law:	1. Cost $200	2. Cost $50
Very much in favor of law..	9.5%	45.2%
Somewhat in favor of law...	25.0	25.8
Somewhat against law......	21.6	9.0
Very much against law.....	43.9	20.0

3a. Even cars properly equipped with emmision control equipment might still pollute the air if the equipment was not properly maintained. How would you feel about a law requiring periodic inspection of the emission control system to assure that it was working properly? ("X" ONE ONLY)

Very much in favor of law	Somewhat in favor of law	Somewhat against law	Very much against law
57.4%	24.7%	9.9%	8.0%

3b. Assuming you had to have your car inspected at least once a year, what would you consider a reasonable cost for the inspection? (WRITE IN AMOUNT)

$ 5.48

3c. Assuming you had to have your car inspected at least once a year, where do you think the inspection should be made? ("X" ONE ONLY)

At state-operated inspection centers.....	41.9%
At city-operated inspection centers......	9.4
At local service stations or garages.....	45.6
At some other place (Specify):	3.1

4a. Even if all autos were equipped with properly maintained emission control systems, some cities might still have auto air pollution problems due to the large number of cars either on the streets at the same time or concentrated in particular areas. Listed below are several possible ways to reduce pollution under one or both of these conditions. Please tell me how you feel about each of these proposals. ("X" ONE ON EACH LINE)

+2 +1 0 0 -1 -2

Proposal	To Me This Plan Is: Very Acceptable	Somewhat Acceptable	Neither Acceptable Nor Unacceptable	Somewhat Unacceptable	Very Unacceptable
a. Gasoline rationing	1.3	3.1	4.4	6.3	▲84.9
b. Very high ($500) registration fee per auto	1.3	0.6	1.3	3.8	93.0▲
c. Very high ($500) registration fee per auto but only for the second, third, etc., auto	3.2	3.8	1.0	14.1	▲76.9
d. Prohibit traffic and parking in central business districts	26.5	24.7▲	13.0	16.0	19.8
e. A tax on all day parking in central business districts	15.0	20.0	10.0	▲17.5	37.5
f. A tax on parking in central business districts regardless of whether a person parked only one hour or all day	10.9	12.2	8.3	17.3▲	51.3
g. Tolls on exit ramps of major freeways and expressways	3.1	6.9	8.2	15.7	▲66.0
h. Tolls on exit ramps of major freeways and expressways but only when traffic was heavy	4.4	7.6	8.9	14.6	▲64.6
i. Restrictions on non-essential auto travel during times of high pollution by issuance of special license plates or vehicle stickers	8.9	15.2	8.2	15.8▲	51.9
j. Turn some existing lanes into "bus only" and "car pool only" lanes on major expressways and streets	47.5	▲24.7	9.3	9.9	8.6

▲Weighted mean for each answer

4b. Which of the proposals listed above would be the most acceptable? (Give Letter:) J - 55.5%
D - 25.2

4c. Which would be most unacceptable? .... (Give Letter:) B - 50.0%
A - 44.4

QUESTIONS 5-8 ASK FOR INFORMATION RELATING TO OTHER HOUSEHOLD MEMBERS. CONSULT THEM, IF NECESSARY, FOR THE ANSWERS.

5a. How often do the various members of your household travel by public transportation? (For example, by bus, subway, or commuter train.)

	Husband	Wife	Children (Over 16 Years Old)
Three or more times a week	1.3%	1.2%	5.8%
One or two times a week	1.3	1.2	--
Once a month	0.7	1.2	--
Once every three months	0.7	4.3	1.9
Never	92.1	91.9	52.9
No household member	3.9	--	39.4

5b. Please rate each household member's reason for using public transportation. (Rate the most important reason "1", the next most important "2", the next "3", etc. If a household member never uses public transportation, "X" the "never use" box at the bottom of the list.)

5c. Please rate each household member's reasons for traveling by auto. Follow the same procedure as in Question 5b. (WRITE IN BELOW UNDER 5c)

	5b. Public Transportation			5c. Auto Transportation		
Reasons	Husband	Wife	Children (Over 16 Years Old)	Husband	Wife	Children (Over 16 Years Old)
a. Cheaper				6	7	7
b. Faster				3	3	3
c. More comfortable				5	4	4
d. Safer for passenger				8	8	7
e. Less congested				6	6	6
f. More available		See Comments		2	2	2
g. More flexible (I can come and go as I please)	Not enough of the respondents use transit.			1	1	1
h. More relaxing (able to read while traveling)					-- not applicable --	
i. Need car during the day				4	4	4
j. I do not have a driver's license					-- not applicable --	
k. Car is not available when I need it					-- not applicable --	
l. Other (Specify): ____________					-- see comments --	
m. Never use ("X" Box)						

5d. Again, consulting other members of your household, please rate in order of effectiveness which items below you feel would be most effective in encouraging the use of public transporation. (Rate the most effective item a "1", the next most effective "2", the next "3", etc.)

Items:	Husband	Wife	Children (Over 16 Years Old)
Cleaner and newer vehicles..	7	7	7
Faster travel	2	3	3
Air-conditioned vehicles	7	5	5
More frequent service	1	1	1
Lower fares	4	3	3
Parking facilities at stops or stations	5	7	7
Shelters against bad weather at stops or stations	5	5	5
Better security to assure personal safety...........	7	5	9
More conveniently located stops and stations	2	2	2
Other (Specify):			

6a. How would you or other household members feel about traveling to and from work in a car pool? ("X" ONE ONLY)

Very interested	12.7%
Somewhat interested........	24.1
Not at all interested	48.1
Already in car pool.........	9.5
Do not travel to and from work by car..............	5.7

6b. **If it became necessary to restrict the number of cars on expressways and streets in order to reduce pollution and car pools became necessary, how difficult do you think it would be to get into one an existing one or organize one amongst your friends, neighbors and/or work associates. ("X" ONE ONLY)**

Extremely difficult	32.5%
Very difficult	14.4
Somewhat difficult..........	23.1
Somewhat easy.............	15.6
Very easy	6.3
Extremely easy	2.5
Already in car pool.........	5.6

7. **One of the major causes of areas of high pollution is traffic congestion. Pollution could be reduced if traffic congestion and stop-and-go traffic was reduced. Listed below are several ideas for reducing traffic congestion. Please tell me how effective you think each of these ideas would be in reducing congestion and pollution. ("X" ONE BOX FOR EACH IDEA)**

Idea:	Very Effective	Somewhat Effective	Not Effective At All	Would Increase Congestion
	+2	+1 0	0	-1
a. Prohibit parking, loading and unloading on busy streets	▲ 55.7%	36.1%	6.3%	1.9%
b. Increase the number of one-way streets	35.1 ▲	43.5	16.2	5.2
c. Establish reversible lanes on busy streets to be used during rush hours	26.0	▲ 32.5	23.4	18.2
d. Prohibit turns at busy intersections during rush hours	44.4 ▲	40.5	12.4	2.6
e. Widen major streets........................	▲ 55.6	32.7	10.5	1.3
f. Widen major streets at intersections only ..	12.6	▲ 40.4	36.4	10.6
g. Provide pedestrian underpasses and/or overpasses	46.2 ▲	39.1	14.1	0.6
h. Improve timing of traffic signals	▲ 64.6	30.4	4.4	0.6
i. Increase the number and frequency of radio traffic reports....................	19.6 ▲	54.2	26.1	--
j. Turn some existing lanes into "bus only" and "car pool only" lanes on expressways and busy streets	48.4 ▲	38.7	9.7	3.2

Your ideas (Please List):

▲ Weighted mean for each answer

8. **Since traffic congestion is most severe at times when people are going to or coming from work, one alternative for reducing congestion would be to have people start and stop work at different times of the day. That is, some people would start work at 5:00 AM and quit at 2:00 PM, others would work from 7:00 AM to 4:00 PM, others from 10:00 AM to 7:00 PM, etc. How do you feel about this idea? ("X" ONE ONLY)**

Very much in favor.........	33.3%
Somewhat in favor..........	37.7
Indifferent	10.5
Somewhat opposed..........	7.4
Very much opposed.........	11.1

9a. **Please record the model year of each car owned in your household. (WRITE IN BELOW UNDER 9a)**

9b. **Please estimate the number of miles each car was driven in the last year. (WRITE IN NUMBER OF MILES UNDER 9b BELOW)**

9c. **For each car, please estimate what percentage of last year's mileage was accounted for by driving outside your local metropolitan area. (For example, vacation, business trips, short weekend trips, etc.) (WRITE IN BELOW UNDER 9c)**

	9a. Model Year	9b. Last Year's Mileage	9c. Percentage of Mileage Outside Local Area
Car #1	1970	13,137	24%
Car #2	1969	10,936	21
Car #3	1969	10,633	32
Car #4	1966	6,625	49

9d. **How many licensed drivers are there in your household? (WRITE IN)**

Number of Licensed Drivers: 2.18 (avg)

9e. **If better public transportation were available, would you consider disposing of any of the cars you own?**

Yes	7.5%
Maybe	19.3
No	73.3

9f. How many? (WRITE IN) 1.03 cars

10a. Overall, how serious a problem do you think auto air pollution is in your city? ("X" ONE BOX UNDER 10a BELOW)

10b. Overall, how serious a problem do you think auto air pollution is nationwide? ("X" ONE BOX UNDER 10b BELOW)

	10a. City	10b. Nationwide
Very serious problem	51.3%	49.0%
Serious problem	25.0	35.0
Slightly serious problem ...	16.9	15.3
No problem at all	6.9	0.6

11. If you have any views or comments regarding any question or idea, please record them:

FIGURE

CMP
CONSUMER MAIL PANELS
323 SOUTH FRANKLIN STREET · CHICAGO, ILLINOIS 60606

(2-C796)

Dear Panel Member,

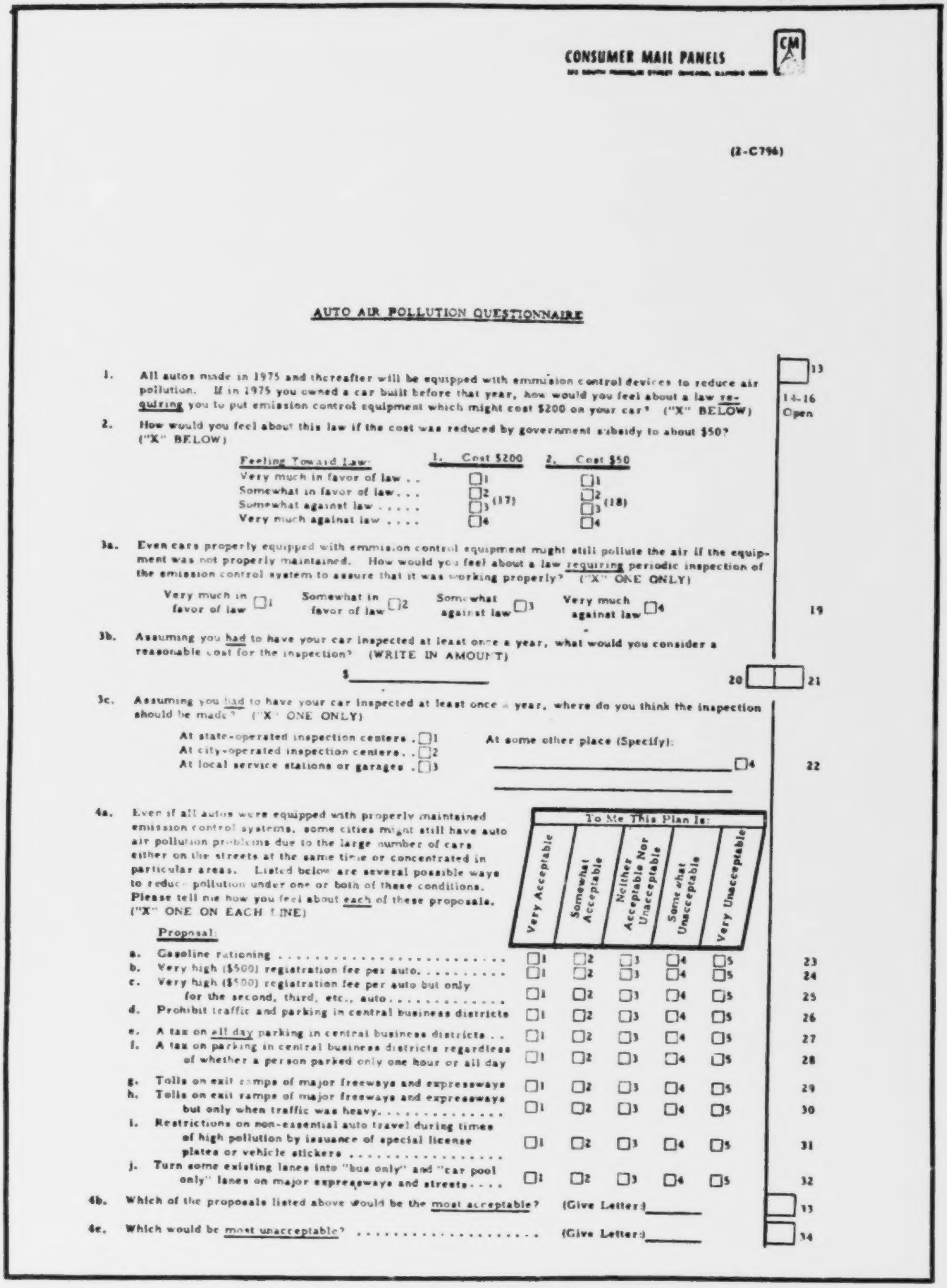
Today, I am sending you a questionnaire which I consider both exciting and interesting. Hopefully, you will too. This questionnaire deals with the important problem of air pollution caused by automobiles.

As you know, autos are a major source of air pollution—especially in metropolitan areas. You probably have read in newspapers or magazines that auto manufacturers are being required to make changes in their cars that will reduce the amount of pollutants coming out of cars. This will be particularly true for cars manufactured in 1975 and thereafter.

Many pollution experts believe, however, that despite these new federal regulations on auto air pollution, other ways will have to be found to further reduce pollution caused by cars. The purpose of this questionnaire is to obtain your reaction to these new auto pollution control ideas being suggested by the experts. In answering some questions, you will probably have to consult other members of your family to get their ideas and reactions. I am sorry if this is inconvenient, but I am sure you will agree that the importance of solving pollution problems is worth making every reasonable effort.

As always, please check each of your answers after you have completed the questionnaire. Then return it to me in the enclosed postage-paid envelope. If you have any additional comments, please write them on the lines provided in Question 11.

Cordially,



CONSUMER MAIL PANELS
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(2-C796)

AUTO AIR POLLUTION QUESTIONNAIRE

☐ 13

14-16 Open

1. All autos made in 1975 and thereafter will be equipped with emmision control devices to reduce air pollution. If in 1975 you owned a car built before that year, how would you feel about a law requiring you to put emission control equipment which might cost $200 on your car? ("X" BELOW)

2. How would you feel about this law if the cost was reduced by government subsidy to about $50? ("X" BELOW)

Feeling Toward Law:	1. Cost $200	2. Cost $50
Very much in favor of law . .	☐1	☐1
Somewhat in favor of law . . .	☐2	☐2
Somewhat against law	☐3 (17)	☐3 (18)
Very much against law	☐4	☐4

3a. Even cars properly equipped with emmision control equipment might still pollute the air if the equipment was not properly maintained. How would you feel about a law requiring periodic inspection of the emission control system to assure that it was working properly? ("X" ONE ONLY)

Very much in favor of law ☐1 Somewhat in favor of law ☐2 Somewhat against law ☐3 Very much against law ☐4 19

3b. Assuming you had to have your car inspected at least once a year, what would you consider a reasonable cost for the inspection? (WRITE IN AMOUNT)

$__________ 20 ☐☐ 21

3c. Assuming you had to have your car inspected at least once a year, where do you think the inspection should be made? ("X" ONE ONLY)

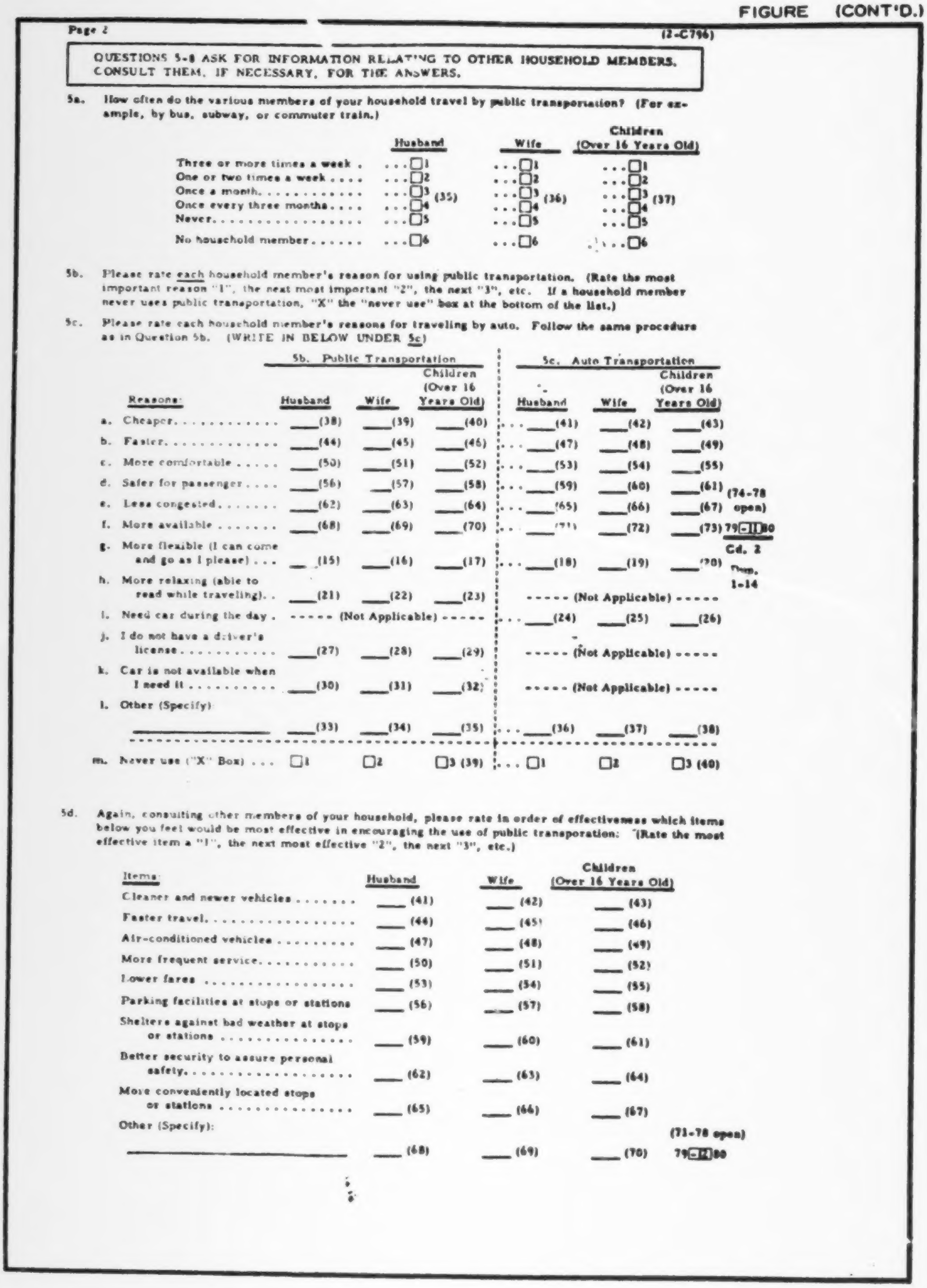
At state-operated inspection centers . ☐1
At city-operated inspection centers . . ☐2
At local service stations or garages . ☐3
At some other place (Specify): __________ ☐4 22

4a. Even if all autos were equipped with properly maintained emission control systems, some cities might still have auto air pollution problems due to the large number of cars either on the streets at the same time or concentrated in particular areas. Listed below are several possible ways to reduce pollution under one or both of these conditions. Please tell me how you feel about each of these proposals. ("X" ONE ON EACH LINE)

	To Me This Plan Is:					
Proposal:	Very Acceptable	Somewhat Acceptable	Neither Acceptable Nor Unacceptable	Somewhat Unacceptable	Very Unacceptable	
a. Gasoline rationing	☐1	☐2	☐3	☐4	☐5	23
b. Very high ($500) registration fee per auto.	☐1	☐2	☐3	☐4	☐5	24
c. Very high ($500) registration fee per auto but only for the second, third, etc., auto.	☐1	☐2	☐3	☐4	☐5	25
d. Prohibit traffic and parking in central business districts	☐1	☐2	☐3	☐4	☐5	26
e. A tax on all day parking in central business districts . .	☐1	☐2	☐3	☐4	☐5	27
f. A tax on parking in central business districts regardless of whether a person parked only one hour or all day	☐1	☐2	☐3	☐4	☐5	28
g. Tolls on exit ramps of major freeways and expressways	☐1	☐2	☐3	☐4	☐5	29
h. Tolls on exit ramps of major freeways and expressways but only when traffic was heavy.	☐1	☐2	☐3	☐4	☐5	30
i. Restrictions on non-essential auto travel during times of high pollution by issuance of special license plates or vehicle stickers	☐1	☐2	☐3	☐4	☐5	31
j. Turn some existing lanes into "bus only" and "car pool only" lanes on major expressways and streets	☐1	☐2	☐3	☐4	☐5	32

4b. Which of the proposals listed above would be the most acceptable? (Give Letter:) ______ ☐ 33

4c. Which would be most unacceptable? . . . . (Give Letter:) ______ ☐ 34



Page 2

(2-C796)

QUESTIONS 5-8 ASK FOR INFORMATION RELATING TO OTHER HOUSEHOLD MEMBERS. CONSULT THEM, IF NECESSARY, FOR THE ANSWERS.

5a. How often do the various members of your household travel by public transportation? (For example, by bus, subway, or commuter train.)

	Husband		Wife		Children (Over 16 Years Old)	
Three or more times a week	☐1	(35)	☐1	(36)	☐1	(37)
One or two times a week	☐2		☐2		☐2	
Once a month	☐3		☐3		☐3	
Once every three months	☐4		☐4		☐4	
Never	☐5		☐5		☐5	
No household member	☐6		☐6		☐6	

5b. Please rate each household member's reason for using public transportation. (Rate the most important reason "1", the next most important "2", the next "3", etc. If a household member never uses public transportation, "X" the "never use" box at the bottom of the list.)

5c. Please rate each household member's reasons for traveling by auto. Follow the same procedure as in Question 5b. (WRITE IN BELOW UNDER 5c)

	5b. Public Transportation			5c. Auto Transportation		
Reasons:	Husband	Wife	Children (Over 16 Years Old)	Husband	Wife	Children (Over 16 Years Old)
a. Cheaper	___(38)	___(39)	___(40)	___(41)	___(42)	___(43)
b. Faster	___(44)	___(45)	___(46)	___(47)	___(48)	___(49)
c. More comfortable	___(50)	___(51)	___(52)	___(53)	___(54)	___(55)
d. Safer for passenger	___(56)	___(57)	___(58)	___(59)	___(60)	___(61)
e. Less congested	___(62)	___(63)	___(64)	___(65)	___(66)	___(67)
f. More available	___(68)	___(69)	___(70)	___(71)	___(72)	___(73)
g. More flexible (I can come and go as I please)	___(15)	___(16)	___(17)	___(18)	___(19)	___(20)
h. More relaxing (able to read while traveling)	___(21)	___(22)	___(23)	----- (Not Applicable) -----		
i. Need car during the day	----- (Not Applicable) -----			___(24)	___(25)	___(26)
j. I do not have a driver's license	___(27)	___(28)	___(29)	----- (Not Applicable) -----		
k. Car is not available when I need it	___(30)	___(31)	___(32)	----- (Not Applicable) -----		
l. Other (Specify): ________	___(33)	___(34)	___(35)	___(36)	___(37)	___(38)
m. Never use ("X" Box)	☐1	☐2	☐3 (39)	☐1	☐2	☐3 (40)

(74-78 open)
79 -1 80
Cd. 2
Dup. 1-14

5d. Again, consulting other members of your household, please rate in order of effectiveness which items below you feel would be most effective in encouraging the use of public transporation: (Rate the most effective item a "1", the next most effective "2", the next "3", etc.)

Items:	Husband	Wife	Children (Over 16 Years Old)
Cleaner and newer vehicles	___ (41)	___ (42)	___ (43)
Faster travel	___ (44)	___ (45)	___ (46)
Air-conditioned vehicles	___ (47)	___ (48)	___ (49)
More frequent service	___ (50)	___ (51)	___ (52)
Lower fares	___ (53)	___ (54)	___ (55)
Parking facilities at stops or stations	___ (56)	___ (57)	___ (58)
Shelters against bad weather at stops or stations	___ (59)	___ (60)	___ (61)
Better security to assure personal safety	___ (62)	___ (63)	___ (64)
More conveniently located stops or stations	___ (65)	___ (66)	___ (67)
Other (Specify): ________	___ (68)	___ (69)	___ (70)

(71-78 open)
79 -2 80

FIGURE (CONT'D.)

(2-C796) Page 3

Cd. 3

Dup.
1-14

6a. How would you or other household members feel about traveling to and from work in a car pool? ("X" ONE ONLY)

Very interested . . . . ☐1
Somewhat interested . . . . ☐2
Not at all interested . . . . ☐3

Already in car pool. . . . . ☐4 — 15
Do not travel to and from work by car. . . . . ☐5

6b. If it became necessary to restrict the number of cars on expressways and streets in order to reduce pollution and car pools became necessary, how difficult do you think it would be to get into one an existing one or organize one amongst your friends, neighbors and/or work associates. ("X" ONE ONLY)

Extremely difficult . . . . . ☐1
Very difficult . . . . ☐2 — 16
Somewhat difficult . . . . . ☐3
Somewhat easy . . . . ☐4
Very easy. . . . . ☐5
Extremely easy . . . . ☐6
Already in car pool . . . . ☐7

7. One of the major causes of areas of high pollution is traffic congestion. Pollution could be reduced if traffic congestion and stop-and-go traffic was reduced. Listed below are several ideas for reducing traffic congestion. Please tell me how effective you think each of these ideas would be in reducing congestion and pollution. ("X" ONE BOX FOR EACH IDEA)

Idea:	Very Effective	Somewhat Effective	Not Effective At All	Would Increase Congestion	
a. Prohibit parking, loading and unloading on busy streets	☐1	☐2	☐3	☐4	17
b. Increase the number of one-way streets.	☐1	☐2	☐3	☐4	18
c. Establish reversible lanes on busy streets to be used during rush hours.	☐1	☐2	☐3	☐4	19
d. Prohibit turns at busy intersections during rush hours .	☐1	☐2	☐3	☐4	20
e. Widen major streets.	☐1	☐2	☐3	☐4	21
f. Widen major streets at intersections only.	☐1	☐2	☐3	☐4	22
g. Provide pedestrian underpasses and/or overpasses . . .	☐1	☐2	☐3	☐4	23
h. Improve timing of traffic signals.	☐1	☐2	☐3	☐4	24
i. Increase the number and frequency of radio traffic reports	☐1	☐2	☐3	☐4	25
j. Turn some existing lanes into "bus only" and "car pool only" lanes on expressways and busy streets	☐1	☐2	☐3	☐4	26
Your ideas (Please List): ____________________ ____________________	☐1	☐2	☐3	☐4	27

8. Since traffic congestion is most severe at times when people are going to or coming from work, one alternative for reducing congestion would be to have people start and stop work at different times of the day. That is, some people would start work at 5:00 AM and quit at 2:00 PM, others would work from 7:00 AM to 4:00 PM, others from 10:00 AM to 7:00 PM, etc. How do you feel about this idea? ("X" ONE ONLY)

Very much in favor . . . . . ☐1
Somewhat in favor . . . . . ☐2
Indifferent. . . . . ☐3 — 28
Somewhat opposed . . . . . ☐4
Very much opposed . . . . . ☐5

(PLEASE CONTINUE ON THE NEXT PAGE)

FIGURE

Page 4

(2-C796)

9a. Please record the model year of each car owned in your household. (WRITE IN BELOW UNDER 9a)

9b. Please estimate the number of miles each car was driven in the last year. (WRITE IN NUMBER OF MILES UNDER 9b BELOW)

9c. For each car, please estimate what percentage of last year's mileage was accounted for by driving outside your local metropolitan area. (For example, vacation, business trips, short weekend trips, etc.) (WRITE IN BELOW UNDER 9c)

	9a. Model Year	9b. Last Year's Mileage	9c. Percentage of Mileage Outside Local Area	
Car #1	____	________	___%	29 ☐☐☐ 31
Car #2	____	________	___%	32 ☐☐☐ 34
Car #3	____	________	___%	35 ☐☐☐ 37
Car #4	____	________	___%	38 ☐☐☐ 40

9d. How many licensed drivers are there in your household? (WRITE IN)

Number of Licensed Drivers: ________ ☐ 41

9e. If better public transportation were available, would you consider disposing of any of the cars you own?

Yes ☐1
Maybe ☐2 → 9f. How many? (WRITE IN) _____ cars
No ☐3

42 ☐☐ 43

10a. Overall, how serious a problem do you think auto air pollution is in your city? ("X" ONE BOX UNDER 10a BELOW)

10b. Overall, how serious a problem do you think auto air pollution is nationwide? ("X" ONE BOX UNDER 10b BELOW)

	10a. City	10b. Nationwide
Very serious problem.	☐1	☐1
Serious problem	☐2 (44)	☐2 (45)
Slightly serious problem. . . .	☐3	☐3
No problem at all.	☐4	☐4

11. If you have any views or comments regarding any question or idea, please record them:

____
____
____
____
____
____
____
____

(46-78 open)
79 -3 80

Thank you for your help. Please check your answers and then return the questionnaire to me in the enclosed postage-paid envelope.

APPENDIX F

A REPORT ON THE EXPERIENCE OF THE SAN DIEGO AIR POLLUTION CONTROL DISTRICT ON CONTROL OF HYDROCARBON EMISSIONS FROM GASOLINE MARKETING

1.0 INTRODUCTION

1.1 Purpose

A trip to San Diego was made by Peter J. Weller on 8 October 1972 for the purpose of gathering information from the San Diego Air Pollution Control District (SDAPCD) on the control of hydrocarbon (HC) emissions from gasoline marketing.

1.2 Contacts

The following personnel were contacted:

Clark Gaulding, Deputy Air Pollution Control Officer
John Farnsworth, Senior Air Pollution Engineer
Barnard R. McEntre, Air Pollution Engineer
Ray Skoff, Air Pollution Engineer

All work at:

County of San Diego Air Pollution Control District
Department of Public Health
1600 Pacific Highway
San Diego, California 92101

(714) 236-3826

(McEntre and Skoff provided me with most of the information described in this report.)

2.0 TECHNICAL INFORMATION

2.1 General System Design

2.1.1 Baseline System

The baseline system is as in Figure 1. The tank truck fills an underground storage tank at the service station and car tanks are filled from pumps which bring gasoline from the underground tank. The disadvantages of this system are:

(1.) Since the temperature of the gasoline in the tank truck is very probably (in moderate to hot climates) higher than the gasoline temperature in the underground storage tank, the total vapor

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pressure in the underground tank is increased. Normally a 1.0 PSI relief valve is used for underground tanks; if the increase in vapor pressure exceeds this, gasoline vapor will be emitted to the atmosphere. (See Attachment A)

(2.) The empty car tank is similarly full of vapor, which is displaced to the atmosphere as the car tank is refilled.

(3.) The topcaps on the tank truck are opened during the transfer of gasoline to the underground tank. This allows air to enter the truck tank and gasoline vapor to exit from it. The air in the truck forms (according to McEntre) an explosive mixture* with the gasoline vapor in the truck. Thus, the driver returns to the bulk terminal with a highly dangerous cargo.

2.1.2 Recovery by Condensation

To recover vapor displaced from the underground tank (or car tank), some systems condense the vapor and either hold the condensate or return it to storage in the underground tank. Typically 10% of the hydrocarbon throughput is lost to the atmosphere with such a system.

2.1.3 Recovery of Adsorption

Some systems use carbon canisters to adsorb the vapor. The canister may be periodically back-flushed (without removal) or may be removed and the trapped gasoline destroyed or recovered.

2.1.4 Recovery by Vapor-Return

With a vapor-return system, a vapor line running from the underground tank to the tank truck carries displaced vapor from the tank back to the truck (See Figure 2). The truck is kept closed, except for the fill line and vapor line to the underground tank. When filling of the underground tank is complete, the truck returns to the bulk terminal with a load of saturated (and, therefore, non-explosive) gasoline vapor.

---

* Minimum air-fuel ratio (weight basis) for explosive mixtures is 9; optimum (ie, most effective for combustion) ratio for explosive mixtures is 14 to 16.

Vapor-return applied to car tank filling takes a similar form. A vapor line running parallel to the gasoline line used for filling car tanks retuns displaced vapor to the storage tank. Both vapor-return applications require a vapor-tight coupling with each tank.

2.2 Specific Systems and Hardware

2.2.1 Names and Addresses of Manufacturers

Attachment B includes a list of system and hardware suppliers. Those marked "out" have withdrawn their interest; those marked with an "X" seem to be the most promising or furthest-developed.

2.2.2 Descriptions of Systems and Hardware

See Table 1.

3.0 LEGAL AND POLITICAL INFORMATION

3.1 Rules 61 and 63

Attachment C is a package sent by Gaulding to gasoline marketing operators. It includes the applicable SDAPCD rules (61 and 63) and a compliance form for permitting. Key aspects of these rules are:

Rule 61: (1.) Lower tank size limit for control requirement is 250 gal.

(2.) Last paragraph in (a) is subject to misinterpretation and should be more explicit.

Rule 63: (1.) Lower tank size limit for control requirement is 250 gal. for stationary tanks and 5 gal. for boat and MV tanks. (Average ranch or farm storage tank is 550 to 1000 gal.; filling station tanks range from 8000 to 10000 gal.)

(2.) "All" in line 11, sentence beginning with "Loading ..."is defined as 100% by SDAPCD.

(3.) Items (1) and (2) of the rule requires 90% efficiency for absorption and condensation and 100% efficiency ("all") for fuel handling (e.g., vapor return) systems.

(4.) Existing sources must have submitted a compliance schedules by 1 July 1972* and must be in compliance by 1 January 1974.

---

* The date for this requirement has not been enforced rigorously - some schedules have been received, others are in progress.

3.2 Legal and Political History

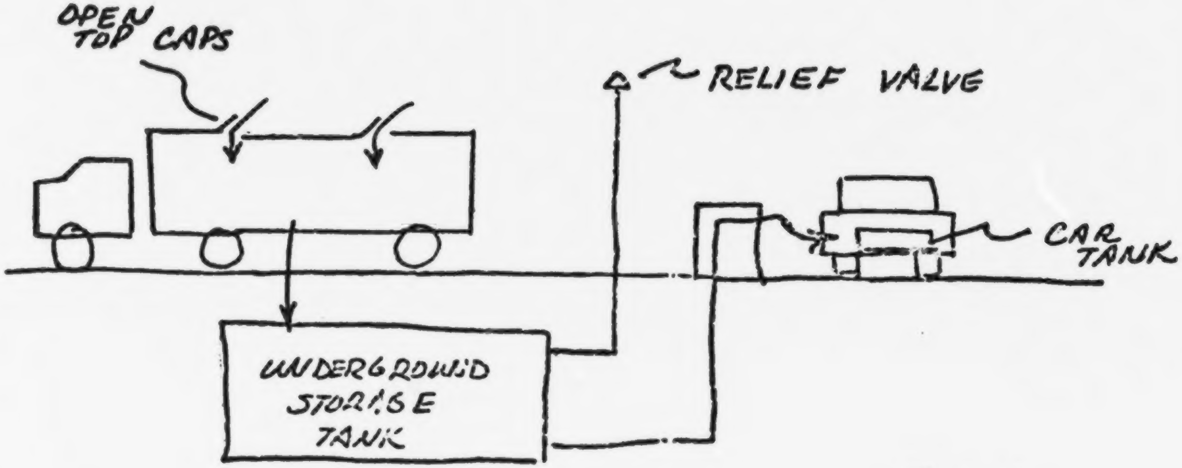
3.2.1 Suit by California Oil Jobbers Assoc.

COJA supplies gasoline to private accounts and independent service stations. It filed a suit recently to challenge the rules but the suit has been dropped because COJA did not exhaust the administrative procedures specified in the rules (namely, the right of hearing and appeal). A major contention is that COJA will be hurt economically by the new rules, but the organization has not been able to show an economic disadvantage.

3.2.2 Filling Stations

One station operator recently applied for authority to construct a station in San Diego. The application was initially rejected because of insufficient control, but the operator resubmitted the application, this time with a description of a recovery system. Action on this application has been delayed pending the development of tank farm facilities for disposal of vapor recovered from vapor-return systems at filling stations.

Evaluation of several other filling station applications is underway. Generally oil companies with existing or planned stations in San Diego seem to be complying with the rules. This may or may not actually be the case; it will become definite in the near future.



OPEN TOP CAPS
RELIEF VALVE
CAR TANK
UNDERGROUND STORAGE TANK

Fig. 1
BASELINE SYSTEM

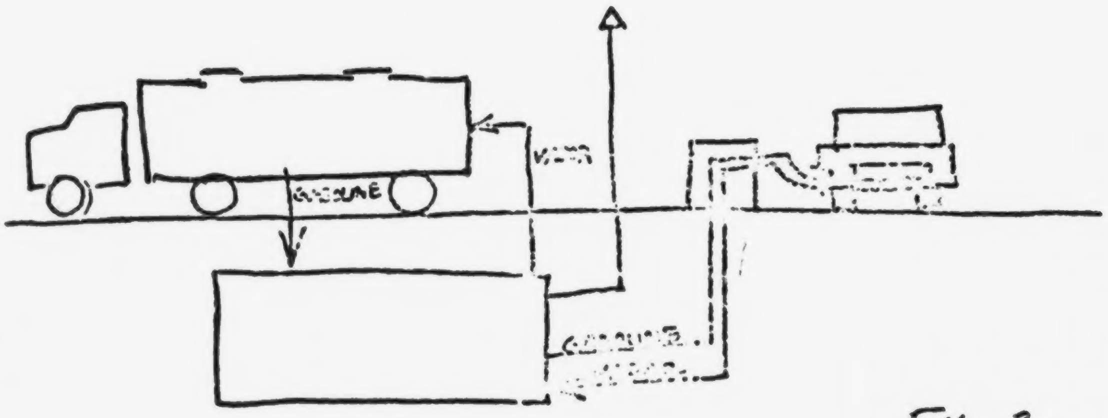

GASOLINE
VAPOR
GASOLINE
VAPOR

FIG. 2
VAPOR RETURN SYSTEM

Supplier	Description	Approximate Capital Cost*	Status
Atlantic Engineering	Condenser. Condensate is returned to underground storage tank.	$5000	Available
Calgon Corp. (Pittsburgh Activated Carbon Div.)	Adsorber. Replaceable carbon canisters; OPW pump nozzles are used. System being tested at San Diego County Operational Center, where county vehicles are serviced. PAC has funded modification of the Center.	--	Developmental
Dover Corp. (OPW Div.)	Nozzle only. See Fig. 3. This is the only commercially available nozzle at present.	$65 (Price will probably be reduced to $35 if/when nozzles are produced in large quantities)	Available
Ocean Resources, Inc.	Definition of system is presently vague	Not determined	Unknown
Shields, Harper & Co.	Technical description has not yet been disclosed. Shields, Harper & Co. will own and lease out their recovery equipment. They will also own all gasoline recovered.	--	Developmental
Vaporex	System reduces the volume of entrained air mixed with vapor and returns recovered gasoline to storage tank. (Major restraint on this type system is that recovered gasoline must be at same temperature as gasoline in storage tanks.) A prototype is being used by Chula Vista Yellow Cab Co.	$1500	Prototype available
Russell, Birdsall & Ward (RBW)	Adsorber. Parallel carbon canisters. One canister is heated and backflushed by vacuum to the storage tank while the other remains in operation. Recovered vapor is bubbled thru liquid gasoline in storage tank. System includes a nozzle design (see Fig. 4).	$2300	Developmental

*Does not include installation and peripheral hardware (piping, valves, etc.) These estimated costs are volatile.

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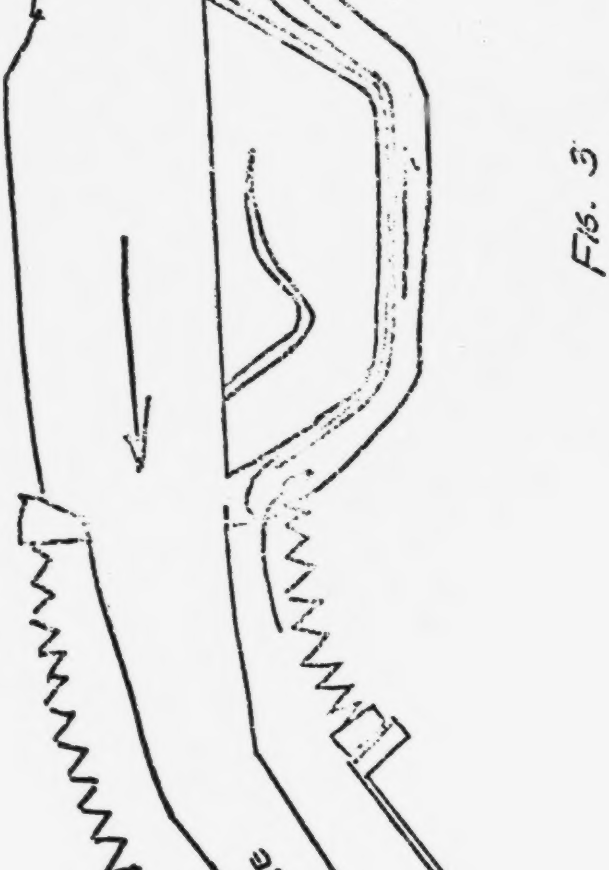
GASOLINE
VAPOR
VAPOR

FIG. 3

OPW NOZZLE

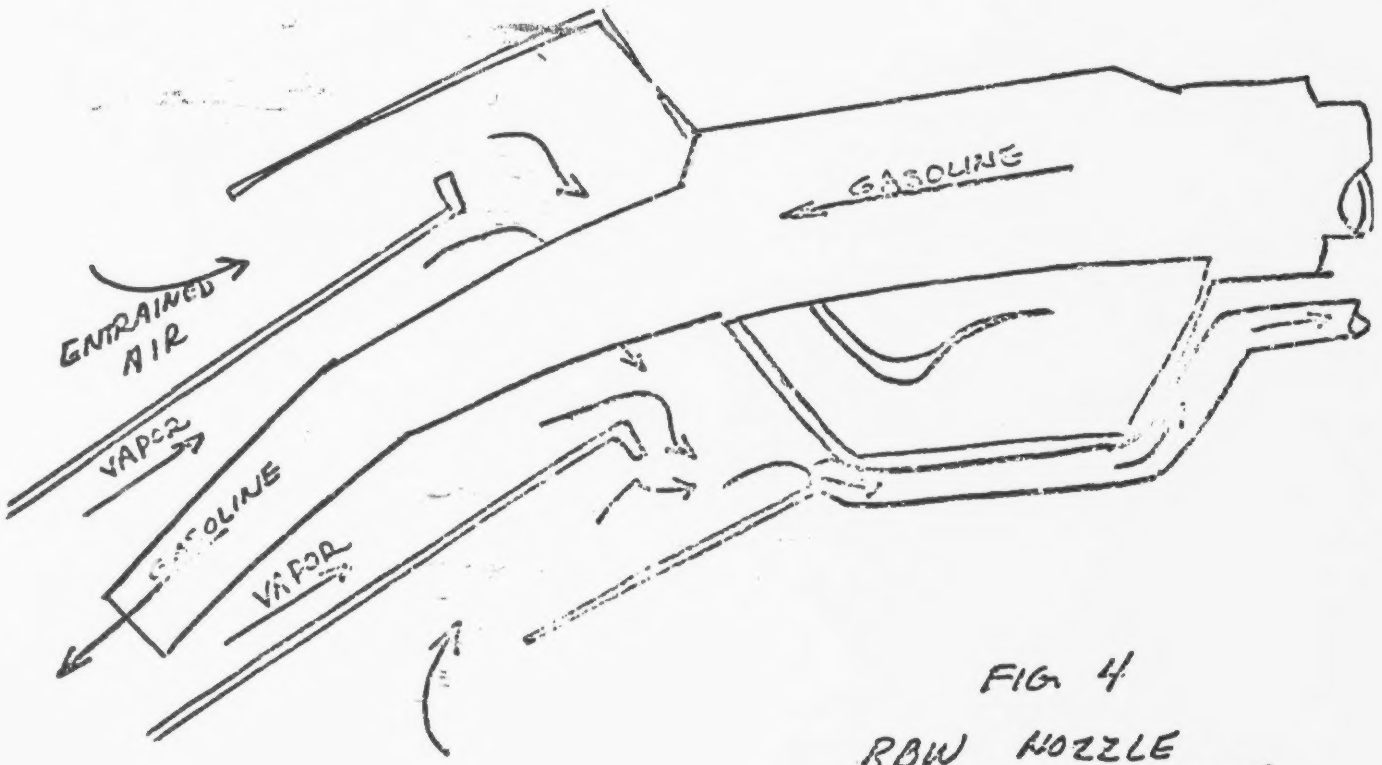
GASOLINE
ENTRAINED AIR
VAPOR
GASOLINE
VAPOR

FIG. 4

RBW NOZZLE DESIGN

Attachment A: Example Calculation of Pressure Increase in Underground Storage Tank During Filling (McEntre)

Estimate (considered conservative):

Temperature of gasoline in truck = 90°F
Temperature of gasoline storage tank = 70°F

Assume:

2000 gal. gasoline in truck
400 gal. gasoline initially in storage tank

Thus:

Temperature of mixture after filling = 87°F

Initial tank pressure (before filling):

gasoline vapor: 6.8 PSIA
tank air: 7.9
total: 14.7 PSIA

Tank pressure after filling:

gasoline vapor: 9.4 PSIA
tank air: 7.9
total: 17.3 PSIA

Increase in vapor pressure = 17.3 - 14.7 = 2.6 PSIA

County of San Diego

DEPARTMENT OF PUBLIC HEALTH

1600 PACIFIC HIGHWAY SAN DIEGO CA 92101
TELEPHONE 239 7711

J B ASKEW M D M P H
DIRECTOR OF PUBLIC HEALTH

Gentlemen:

This office recently mailed a package of material (letter, forms, etc.) regarding the requirements of Rules 61 and 63 of the County of San Diego Air Pollution Control District to all known affected parties. In response to that correspondence, you made a verbal or written request to the District that you be provided with the names of individuals or firms that have contacted the District indicating that they have an interest in or capability for the development of equipment that may be required to comply with Rules 61 and 63.

The District is not routinely issuing such a listing; however, in an effort to assist in any reasonable way possible, the District is providing such a listing to you and any others who have made specific requests. Please find the subject listing enclosed.

In providing this information, the District wishes to make several points clear. The list includes in alphabetical order all persons or companies that have specifically indicated to the District that they are interested in developing or assisting in the development of equipment that might be required to meet Rules 61 and 63. The District does not consider the listing complete, since in all likelihood there are others who have not contacted the District who have a similar interest or capability; therefore, the District intends to augment the list to include anyone who requests that they be included. Finally, the District expressly disavows any advance endorsement of any individual or company on the list, or of any equipment or methodology that they may recommend; the District will evaluate equipment and/or systems only when incorporated in specific Compliance Schedules or in applications for Authority to Construct. Any questions regarding this matter should be directed to me or to Mr. John Farnsworth.

Sincerely,

Clark L. Gaulding

CLARK L. GAULDING, CHIEF
Air Pollution Control Service

CLG:mj
Attachment

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ATTACHMENT B, CONTIN.

INDIVIDUALS OR FIRMS INDICATING INTEREST IN OR CAPABILITY FOR DEVELOPMENT OF EQUIPMENT FOR

Rules 61 and 63 Compliance

County of San Diego Air Pollution Control District

The following listing has been made available by the San Diego County Air Pollution Control District on request and as specifically qualified by the District letter dated   The listing has no meaning except that expressly stated in that letter.

out
Aeroquip Corporation
Barco Division
Barrington, Illinois 60010

X
Atlantic Engineering, Inc.
2275 W. Lincoln Ave.
Anaheim, CA 92801

6170 Thornton Ave.
Newark, CA 94560
(Attn: John C. Taylor)

out
The Bendix Corporation
Bendix Center
Southfield, Michigan 48075

X
Calgon Corporation
Pittsburgh Activated Carbon Div.
P.O. Box 1346
Pittsburgh, PA 15230

Coast Equipment Exchange
6411 Maple Street
Westminster, CA 92683

Cyrus, Mr. John E.
John E. Cyrus Co.
P.O. Box 10161
San Diego, CA 92119

X
Dover Corporation/OPW Div.
2735 Colerain Ave.
Cincinnati, Ohio 45225

Emco Wheaton, Inc.
Chamberlain Blvd.
Conneaut, Ohio 44030

Gulf Environmental Systems
P.O. Box 608
San Diego, CA 92112

Hamilton Constructors
904 Westminster Ave.
Alhambra, CA 91803

Hazlett, Wesley W.
1089 Indian Village Road
Pebble Beach, CA 93953

Kenton Equipment Company
3200 Kurtz Street
San Diego, CA 92110

Kachant, Fritz A., Inc.
3475 E. Street
San Diego, CA 92102

North American Carbon, Inc.
Box 19737
Columbus, Ohio 43219

X (?)
Ocean Resources, Inc.
P.O. Box 2244
La Jolla, CA 92037

Parker-Hannifin
Fueling Division
18321 Jamboree Blvd.
Irvine, CA 92664

Rheem Superior, Div. of Rheem Mfg. Co.
6155 South Eastern Ave.
Los Angeles, CA 90040

X
Shields, Harper & Co.
5107 Broadway
Oakland, CA 94611

Tokheim Corporation
1600 Wabash Ave.
Ft. Wayne, Ind. 46801

X
Vaporex
900 Orange Fair Lane
Anaheim, CA 92801
(Attn: B.B. Murray)

Wiggins Connectors, Div. of Wiggins
500 Triggs Street
Los Angeles, CA 90022

X
RUSSELL, BIRDSALL, AND WARD (RB & W)
16000 W. 9 MILE RD, SUITE 600
SOUTHFIELD, MICH 48075
(ATTN: [illegible])

9/25/72 (Revised)

County of San Diego

DEPARTMENT OF PUBLIC HEALTH

J. B. ASKEW, M.D., M.P.H.
DIRECTOR OF PUBLIC HEALTH

[illegible] PACIFIC HIGHWAY SAN DIEGO CA 92101
TELEPHONE 233-7[illegible]

On January 17, 1972, the Board of Supervisors of the County of San Diego, acting as Directors of the San Diego County Air Pollution Control District, passed two new rules, 61 and 63, which will affect all service stations and associated support facilities in the County. These two rules, which are reproduced in full and enclosed along with Rules 10 and 40 relating to permits and fees, affect the storage and transfer of gasoline from bulk supplier to ultimate consumer.

These Rules establish a compliance date of January 1, 1974, on facilities that are in existence or are being constructed on June 30, 1972, (facilities constructed after June 30, 1972, must comply at start of operation). In order to satisfy the Air Pollution Control District that the Rules will be met by January 1, 1974, a compliance schedule showing methods to be used in meeting the requirements, and critical dates in the implementation of these methods, must be submitted by July 1, 1972. If this compliance schedule is not submitted by July 1, the requirements of the Rules become effective immediately; if the submitted compliance schedule is not adhered to, the Rules become effective on the date the schedule is not adhered to.

Thus, the compliance schedule must be carefully considered before submission and followed after submission; a Rule 61-63 compliance schedule form is enclosed for your use in submitting the schedule. However, submission of this form without supporting explanation will not constitute an acceptable compliance schedule in most cases. The explanations required in items No. 1,2, and 3 of the form should be augmented with schematic drawings and diagrams, and the major elements of the control system should be described in sufficient detail to provide a clear understanding of the basic technical concepts involved.

Serving all of the incorporated and unincorporated areas of San Diego County

A consolidated schedule may be acceptable in certain cases with prior approval from the District: an example would be one owner contemplating the same corrective measures for several similar facilities at the same or different locations. To resolve the details of such a schedule, or any other questions regarding this matter, please contact the Senior Air Pollution Engineer, Mr. John K. Farnsworth, or me, at 239-7711, extension 631. Your cooperation in this matter will be appreciated.

The instructions contained in this letter pertaining to compliance schedules do not apply to gasoline storage tanks and gasoline transferring equipment at locations where the equipment is used solely for agricultural operations in the growing of crops, or raising of fowls or animals. This exemption is pursuant to certain provisions of the State Health and Safety Code pertaining to permits for agricultural operations and a District administrative decision on the status of compliance schedules for operations not requiring permits. However, although a compliance schedule and Air Pollution Control District permit may not be required for agricultural equipment, compliance with Rules 61 and 63 by July 1, 1974, is required, and owners of such equipment should make their own plans for compliance by that date.

Sincerely,

Clark L. Gaulding

CLARK L. GAULDING, Chief
Air Pollution Control Service

CLG:ba
Encl. Rules 10,40,61,63
Compliance Form

RULE 61. STORAGE OF VOLATILE ORGANIC COMPOUNDS.

(a) A person shall not hold or store any volatile organic compound having a vapor pressure of 1.5 pounds per square inch absolute or greater, under actual storage conditions, in any stationary tank, reservoir or other container of more than 250 gallons capacity unless such tank, reservoir or other container is a pressure tank maintaining, at all times, working pressures sufficient to prevent hydro carbon vapor or gas loss to the atmosphere, or is designed and equipped with one of the following vapor loss control devices or systems, properly installed, in good working order, and in operations:

(1) A floating roof, consisting of a pontoon type or double deck type roof, or internal floating cover, resting on the surface of the liquid contents and equipped with a closure seal, or seals, to close the space between the roof edge and tank wall. (This control equipment is not appropriate if the volatile organic compound has a vapor pressure of 11 pounds per square inch absolute or greater under actual storage conditions.) All tank gauging and sampling devices shall be gas-tight except when gauging or sampling is taking place.

(2) A vapor collection and disposal system, consisting of a vapor gathering system capable of collecting the volatile organic compound vapors and gases discharged, and a vapor disposal system as prescribed in Rule 63. All tank gauging and sampling devices shall be gas-tight except when gauging or sampling is taking place.

(3) Other equipment of at least equal efficiency to the equipment specified in (1) and (2) above, provided plans for such equipment are submitted to and approved by the Air Pollution Control Officer.

Pressure tanks required by this rule may be equipped with one-way automatic pressure relief valves necessary to meet any other requirements of law.

(b) Notwithstanding subdivision (a) of this Rule, a person holding or storing the above specified compounds in a stationary tank, reservoir or other container of more than 250 gallons capacity which was either in existence on June 30, 1972 or in the process of being installed on said June 30, 1972 on the premises where they were to be used, shall not be subject to the provisions of subdivision (a) of this Rule until January 1, 1974, provided, however, that such person is hereby required to file on or before July 1, 1972 a compliance schedule with the Air Pollution Control Officer showing how the person will bring his operations into compliance with subdivision (a) of this Rule on or before said January 1, 1974. Failure to file such compliance schedule or abide by its terms shall render the prohibition contained in subdivision (a) of this Rule immediately applicable to such person on July 1, 1972 or on the date of said person's failure to abide by said compliance schedule.

RULE 63. VOLATILE ORGANIC COMPOUND LOADING FACILITIES.

(a) A person shall not load or allow the loading of volatile organic compounds having a vapor pressure of 1.5 pounds per square inch absolute or greater, under actual storage conditions into any tank truck or trailer, railroad tank car, locomotive, aircraft, stationary storage tank with a capacity of more than 250 gallons, or boat or motor vehicle fuel tank having a capacity greater than 5 gallons from any loading facility unless such tank or loading facility is equipped with a vapor collection and disposal system, or its equivalent, properly installed, in good working order, and in operation. Loading shall be accomplished in such a manner that all displaced vapor and air will be vented only to the vapor disposal system. A means shall be provided to prevent liquid organic compound drainage from the loading device when it is removed from the hatch, or to accomplish complete drainage before such removal.

The vapor disposal portion of the system shall consist of one of the following:

(1) An absorber system or condensation system with a minimum recovery efficiency of 90 per cent by weight of all the volatile organic compound vapors and gasses entering such disposal system.

(2) A vapor handling system which directs all vapors to a fuel gas system.

(3) Other equipment of at least 90 per cent efficiency, provided plans for such equipment are submitted to and approved by the Air Pollution Control Officer.

Intermediate storage vessels may be used prior to disposal of vapors under 1, 2, or 3, above, provided they are so designed as to prevent release of vapors at any time during use.

(b) Notwithstanding subdivision (a) of this Rule, a person loading or allowing the loading of the above specified compounds in the above specified storage vessels from the above specified loading facilities, either of which were in existence on June 30, 1972 or in the process of being installed for use on said June 30, 1972, shall not be subject to the provisions of subdivision (a) of this Rule until January 1, 1974, provided, however, that such person is hereby required to file on or before July 1, 1972, a compliance schedule with the Air Pollution Control Officer showing how the person will bring his operation into compliance with subdivision (a) of this Rule on or before January 1, 1974. Failure to file such compliance schedule or abide by its terms shall render the prohibition contained in subdivision (a) of this Rule immediately applicable to such person on July 1, 1972 or on the date of said person's failure to abide by said compliance schedule.

—— Rules and Regulation, County of San Diego
Air Pollution Control District; Adopted January 17, 1972

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RULE 10. PERMITS REQUIRED. (a) AUTHORITY TO CONSTRUCT. Any person building, erecting, altering or replacing any article, machine, equipment or other contrivance, the use of which may cause the issuance of air contaminants or the use of which may eliminate or reduce or control the issuance of air contaminants, shall first obtain written authorization for such construction from the Air Pollution Control Officer. A separate authority to Construct will be required for each piece of equipment, product line, system, process line or process that produces a product or performs a service independently of other equipment, product lines, systems, process lines or processes. An Authority to Construct shall remain in effect until the permit to operate the equipment for which the application was filed is granted or denied or the application is cancelled.

(b) PERMIT TO OPERATE. Before any article, machine, equipment or other contrivance described in Rule 10 (Authority to Construct) may be operated or used, a written permit shall be obtained from the Air Pollution Control Officer. No permit to operate or use shall be granted either by the Air Pollution Control Officer or the Hearing Board for any article, machine, equipment or contrivance described in Rule 10 (Authority to Construct), constructed or installed without authorization as required by Rule 10 (Authority to Construct) until the information required is presented to the Air Pollution Control Officer and such article, machine, equipment or contrivance is altered, if necessary, and made to conform to the standards set forth in Rule 20 and elsewhere in these Rules and Regulations. A separate permit to operate will be required for each piece of equipment, product line, system, process line or process that produces a product or performs a service independently of other equipment, product lines, systems, process lines or processes.

(c) POSTING OF PERMIT TO OPERATE. A person who has been granted under Rule 10 a permit to operate any article, machine, equipment, or other contrivance described in Rule 10(b), shall firmly affix such permit to operate, an approved facsimile, or other approved identification bearing the permit number upon the article, machine, equipment, or other contrivance in such a manner as to be clearly visible and accessible. In the event that the article, machine, equipment, or other contrivance is so constructed or operated that the permit to operate cannot be so placed, the permit to operate shall be mounted so as to be clearly visible in an accessible place within 25 feet of the article, machine, equipment, or other contrivance, or maintained readily available at all times on the operating premises.

(d) ALTERATION OF PERMIT. A person shall not wilfully deface, alter, forge, counterfeit, or falsify any permit issued under these Rules and Regulations.

(f) PERMIT TO SELL OR RENT. (1) Any person who sells or rents to ~~[illegible]~~ any other person an incinerator which may be used to dispose of combustible refuse by burning within San Diego County and which incinerator is to be used exclusively in connection with any structure, designed ~~[illegible]~~ and used exclusively as a dwelling for not more than four families, shall first obtain a permit from the Air Pollution Control Officer to sell or rent such incinerator.

(2) Any person who rents to any other person for less than one year any article, machine, equipment, or other contrivance, not exempted from the permit to operate requirement of Rule 11, the use of which may cause the issuance of air contaminants or the use of which may eliminate or reduce or control the issuance of air contaminants shall first obtain a permit from the Air Pollution Control Officer to rent such article, machine, equipment or contrivance. If a person obtains a permit to rent for any such article, machine, equipment or contrivance, such permit shall apply to all like articles, machines, equipment or contrivances rented by said person.

(g) CONTROL EQUIPMENT. Nothing in this rule shall be construed to authorize the Control Officer to require the use of machinery, devices, or equipment of a particular type or design, if the required emission standard may be met by machinery, device, equipment, product, or process change otherwise available.

RULE 40. ~~[illegible]~~ APPLICATION FEES. Every applicant, except any State or local governmental agency or public district, for an authority to construct and/or a permit to operate any article, machine, equipment, or other contrivance, shall pay a filing fee of $40.00 for each application filed. When a single application is submitted for both an authority to construct and a permit to operate, the filing fee shall be $[illegible]. Where an application is filed for a permit to operate any article, machine, equipment or other contrivance by reason of transfer from one person to another, and where a permit to operate had previously been granted under Rule 10 and no alteration, addition or transfer of location has been made, the applicant shall pay a $10.00 filing fee.

Where a single permit to operate has been granted under Rule 10, and where the Air Pollution Control Officer would have issued separate or revised permits for each permit unit included in the original application, the Air Pollution Control Officer may issue such separate or revised permits without fees.

A request for duplicate permit to operate shall be made in writing to the Air Pollution Control Officer within 10 days after the destruction, loss or defacement of a permit to operate. A fee of $5.00 shall be charged, except to any state or local government ~~[illegible]~~ agency or public district, for issuing a duplicate permit to operate.

ATTACHMENT C, CONTD

COUNTY OF SAN DIEGO AIR POLLUTION CONTROL DISTRICT
RULE 61-63 COMPLIANCE SCHEDULE

INSTRUCTIONS: This form is to be completed by the owner for each facility subject to Rules 61, and/or 63. A single copy of each form and any attachments should be submitted. A combined compliance schedule for multiple units of equipment or facilities at more than one location may be acceptable PROVIDED the APCD has granted prior approval for such a combined schedule.

This form is intended as a guide; it should be augmented with additional descriptions, drawings, etc., to provide a clear understanding of the basic technical concepts of the compliance plan.

Storage or Delivery Facility Name ____________________

Location ____________________

Owner (Name) ____________________ Title ____________________

Address of Owner ____________________ Telephone ____________________

Number of Storage Tanks __________ Size ____________________

Number of Delivery Nozzles or Loading Arms ____________________

1. Proposed method for control of venting from storage tanks (Rule 61).

☐ Pressure tank method ☐ Vapor handling system ☐ Other

Explain ____________________

____

2. Proposed method for control of displaced volume from stationary storage tanks during loading of fluid into such tanks (Rule 63).

☐ Absorber or condensation system ☐ Vapor handling system ☐ Other

Explain ____________________

____

3 Proposed method for control of displaced volume from tanks of non-stationary sources during delivery of fluid into such tanks (Rule 63).

☐ Absorber or condensation system ☐ Vapor handling system ☐ Other

Explain ____________________

____

4. Schedule dates for submission of applications for Authority to Construct and Permit To Operate for Items 1, 2, & 3

Item 1. __________ Item 2. __________ Item 3. __________

5. Schedule dates for start of construction or installation for Items 1, 2, 3.

Item 1. __________ Item 2. __________ Item 3. __________

6. Schedule dates for completion of construction or installation and readiness for evaluation for Permits to Operate for Items 1, 2, 3.

Item 1. __________ Item 2. __________ Item 3. __________

Signature of Owner ____________________ Date __________

(Originator should make copy for his records.)

Do Not Write Below (APCD Use Only)

Compliance Schedule: Reviewed By ____________________ Action __________ Date __________

Progress Report Due Dates ____________________

APCD 8 6/72 2M

COUNTY OF SAN DIEGO DEPARTMENT OF PUBLIC HEALTH
1600 PACIFIC HIGHWAY, SAN DIEGO, CA 92101

APPENDIX G

AIR QUALITY FORECASTING SIMULATION MODEL

The state of air quality is influenced by a large number of complex relationships and interactions. Any attempt to forecast future air quality must account for these factors. One method for addressing this problem in a systematic framework involves the use of a computer simulation model. Here, the various relationships affecting air quality (such as transportation controls) can be assessed quantitatively.

The model developed for this study permits the forecasting of future air quality of each Set II pollutant for the 1975 through 1980 period. Basically, the model consists of the following four elements.

- Air Quality Model (RBM)
- Vehicle Population Model (VPM)
- Vehicle Emissions Model (VEM)
- Strategy Assessment Model

Each describes a different facet in the process used to forecast future air quality. Figure 1-G presents a schematic overview of the composition and relationships between the various model elements. Since the model was developed for evaluating the merit of various transportation control measures, it quite naturally focuses with more detail on the mobile as opposed to stationary sources. The model is sufficiently flexible in design, however, to permit a more elaborate description of

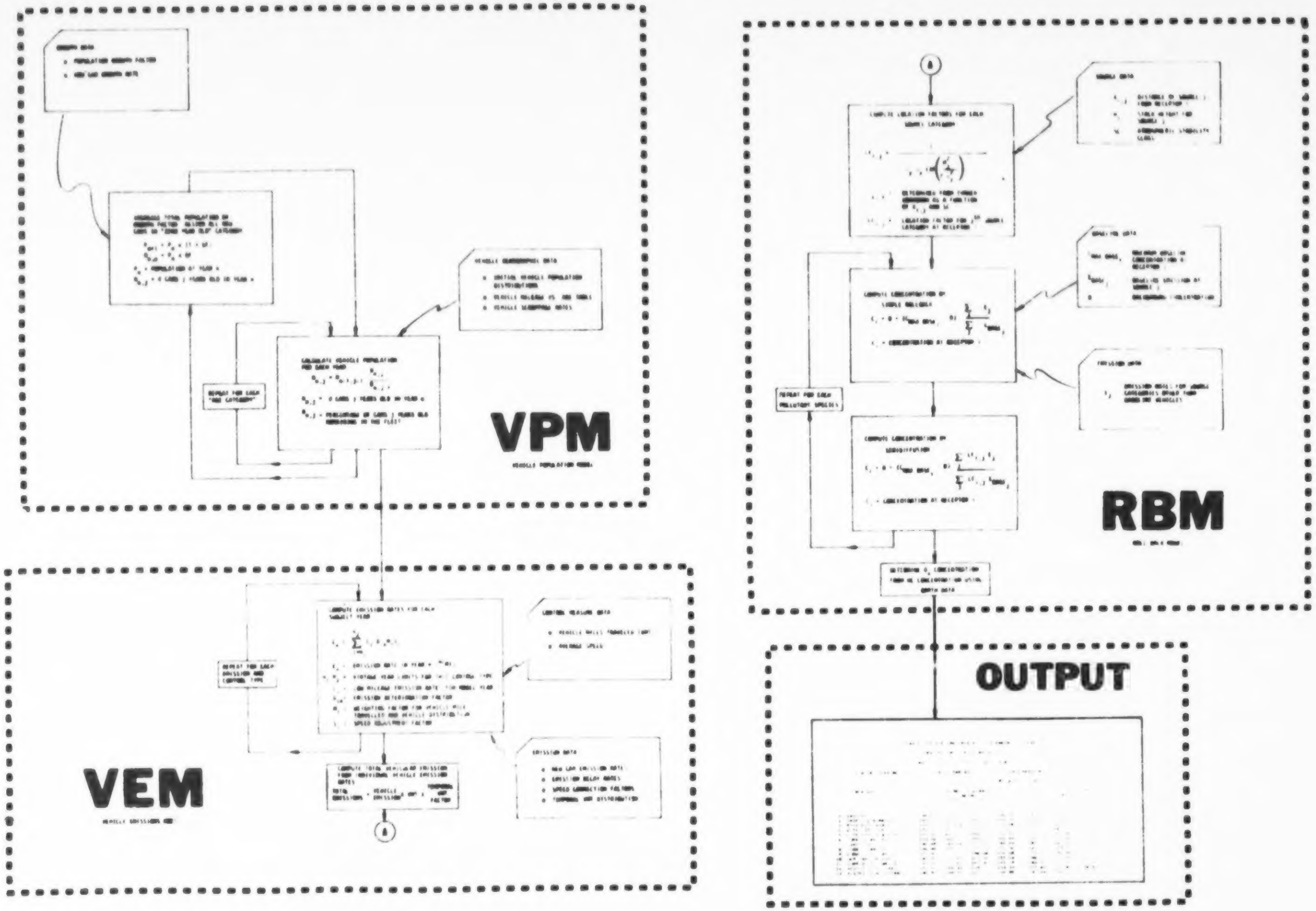
VPM
RBM
VEM
OUTPUT
REPEAT FOR EACH EMISSION AND CONTROL TYPE
CONTROL MEASURE DATA
VEHICLE MILES TRAVELED (VMT)
AVERAGE SPEED
EMISSION DATA
SPEED CORRECTION FACTORS
TEMPORAL VMT DISTRIBUTION
A

Table 1-G. Air Quality Model Schematic

stationary sources, as appropriate. The following presents a more detailed discussion on the basic characteristics of the model.

AIR QUALITY MODEL

Two different methods are used for estimating future air quality. The first one, employing simple roll-back concepts, assumes that regional air quality will improve in direct proportion to reductions in regional emissions. Future air quality is estimated by:

$$AQ_F = AQ_B \cdot [(E_F/E_B) \cdot S_B + (1 - S_B) \cdot GF] \qquad (G\text{-}1)$$

where :

AQ - Regional air quality (F - Final Year, B - Base Year)

E - Motor vehicle emission in region

S - Ratio of motor vehicle emissions to total pollutant emissions in region

GF - Growth factor for stationary source emissions in region

Equation G-2, modified slightly to account for natural background concentration levels, is referred to as "Simple Roll-back" and operates in the form:

$$AQ_{xx} = b + (AQ_{\text{base year}} - b) \cdot \frac{\sum E_{19xx}}{\sum E_{\text{base year}}} \qquad (G\text{-}2)$$

where b is the background concentration level

where σ_y and σ_z are functions of the atmospheric stability class and the distance from source to receptor. h_j is the effective stack height.

The Roll-Back equation using the location factors becomes:

$$AQ_{xx} = b + (AQ_{\text{base year}} - b)\frac{\sum lf_j E_{j,\ 19xx}}{\sum lf_j E_{j,\ \text{base year}}}$$

Since the location factors appear in both the numerator and denominator of the concentration multiplier, only the relative magnitude is important.

As the distance between the receptor and the source increase both σ_z and σ_y increase, the rate of increase depending on the atmospheric stability class.

The atmospheric stability class characterizes those meteorological conditions required by the Air Quality Model. As described in the Turner Workbook [40], the stability class quantifies the turbulent structure of the atmosphere around the area being considered. It depends mainly on the amount of incoming solar radiation, the cloud conditions and surface wind speed. The stability class ranges from A to F, A being the most unstable, F the most stable. Figures correlating σ_y and σ_z with the stability class along with a complete description of the technique are found in the Turner Workbook.

This technique, although simple to use, has some severe restrictions. It does not account for the fact that some emission sources are closer than others to the receptor or problem area. Nor does it consider differences in effective stack height of the various sources. sources. Finally, it ignores meteorological conditions.

The Modified Roll-back, or Semidiffusion Model takes into account some of these effects while retaining the simple form of the roll-back equation. This modification to Simple Roll-back is an attempt to characterize the atmospheric distribution of emissions while avoiding a full scale dispersion model. While these larger models are available they have not been applied to the Houston area planning.

The Semidiffusion Model assigns a relative importance to each source depending on its distance from the receptor, (or hot spot) the prevailing atmospheric stability class, and to a small degree, on the effective stack height of the source. This relative importance index is called the Location Factor (lf).

$$lf_j = \frac{1}{\sigma_y \sigma_z \exp\left(\frac{h_j^2}{2\sigma_3^2}\right)} \quad \text{for a particular source j}$$

The air quality model correlates oxidant concentrations to hydrocarbon values through the use of the observational model relationship presented in Figure 4-A of Appendix A. The model references the total hydrocarbon concentration to derive oxidant concentration values at each year for each strategy.

Table G-1 presents a list of the 8 source categories (both mobile and stationary) used in characterizing the semi-diffusion model for the Houston Region. In general, when controls are applied to mobile sources which are relatively closer to the receptor then their stationary counterparts, the semi-diffusion model will yield lower estimates of pollutant concentrations then the simple roll-back model.

VEHICLE POPULATION MODEL

The Vehicle Population Model (VPM) is a general methodology for analyzing the impact of changes in the vehicle population on resultant vehicle emissions. Used in conjunction with the Vehicle Emission Model, VPM can provide estimates of net emissions for the period 1972 - 1980 under a variety of alternate control measure considerations.

The basic model methodology involves analytically describing the "birth and death" process taking place within the vehicle population itself. Older vehicles are continually aging, with the oldest leaving the population entirely after many years of service. Simultaneously, new vehicles are being added to the population at some pre-assigned rate. Because of this process, the relative weights of various vehicle age groups in determining the net emissions change with time. Any accurate emissions projection must account for this phenomenon.

VPM computes the vehicle age distribution over time, adjusting for both new cars and vehicle attrition. This distribution provides a set of weighting factors for each age class and for each year analyzed.

Table G-1. Emission Source Categories for Houston

1. Uncontrolled Vehicles
2. Controlled Vehicles
3. Post-1974 Vehicles
4. Heavy-Duty Vehicles
5. Crankcase and Evaporative Losses
6. Point Sources
7. Area Sources
8. Other Transportation

Combined with independently estimated vehicle emission rates, this distribution data can lead to emission projections weighted for changes in vehicle population characteristics.

This weighting process is crucial in making accurate projections. Under the current vehicle breakdown, three separate classes of light duty vehicles are considered: uncontrolled (pre 1968), controlled (1968 - 1974) and post 1974. Emission levels of the first group rises substantially over time due to vehicle deterioration. Yet, due to natural attrition processes, their numbers decline. The net contribution of this group depends upon the interaction of both vehicle attrition and deterioration. Similarly, post 1974 vehicles have substantially reduced emission levels. As they enter the population and represent an increasingly large fraction, the population's emissions characteristics will approach those of the post 1974 cars. It is this complex interaction between vehicle attrition, entrance of new cars and resultant population emission levels which is described quantitatively by VPM and which can provide a straightforward mechanism for projecting emission levels over future periods. The emission levels for new cars entering the population are assumed to be in compliance with promulgated standards. The model can also be used for measuring the time related effectiveness of various proposed vehicle control strategies, both singularly and in combination. This can be accomplished by introducing quantitative point estimates of strategy effectiveness and simulating the model over a specified time horizon.

VPM requires the following as basic input:

- Initial vehicle population
- Initial vehicle age distribution
- Population growth rate
- Vehicle attrition rates
- Initial vehicle emission levels by model year
- Emission deteriorate rates by model year

VEHICLE EMISSION MODEL

The Vehicle Emissions Model (VEM) characterizes emission levels for the first five source categories of Table G-1. Equation G-3 presents the relationship used in estimating emission levels for categories one through four.

$$E = \sum_{i = n_1}^{n_2} C_i \, d_i \, M_i \, S_i \, VMT_i \qquad \text{(G-3)}$$

where:

Ci = the new car (low mileage) emission rate for model year i

di = the time decay factor

[illegible] the weighing factor for fraction of vehicle miles traveled

Si = the speed correction factor

VMTi = annual vehicle miles traveled per year for one vehicle in ith model year

M_1, M_2 = time limits for the appropriate category

E = emission rate by vehicle in grams per year

Similarly, equation G-4 shows the relationship for estimating evaporate and crankcase losses

$$E = \sum hi\ Mi\ VMT_i$$

where:

h_i = evaporative and crankcase emission losses for ith model year

Conversion of emission rates from grams per year to grams per second, for incorporation into AQM, requires the use of the diurnal distribution of vehicle miles traveled within the metropolitan area and the pollutant measurement sample basis. Both are used to calibrate annual emission rates with actual traffic flows and peak pollutant levels. The effectiveness of various control measures for these five categories is then applied directly to the resultant emission rates.

STRATEGY ASSESSMENT MODEL

The strategy assessment model is used in characterizing the effectiveness of various vehicular control measures. A measure can be defined (in the model) in terms of: 1) the percentage drops of emission rates in each source category, 2) a change in average speed for light and/or heavy duty vehicles, 3) a VMT multiplying factor, 4) and the new average distances between the sources and the receptor.

These parameters are used to compute total vehicular emission rates which enter into the air quality calculations.

The percentage emissions drops are applied directly to the total vehicular emission rates. Inspection/Maintenance as an example affects only the average emission rates and thus can be defined with percentage drops, 12 for HC, 10 for CO, and 0 for NO_x, with no change in the VMT multiplying factor, speeds or average distances.

The average speeds are used to determine the multiplying factor, Si, in equation G-3. As speed increases, Si decreases in a monotonic but nonlinear fashion, but has no effect on either NO_x emissions or post 1974 vehicles. This parameter, along with the VMT multiplying factor, allows the analysis of road improvement and traffic control measures.

The VMT multiplying factor affects all gasoline powered vehicular emission rates in a similar manner. Using a value of 0.5 means half the base year mileage can be eliminated by this strategy, resulting in a 50% drop in mobile source emission rates. The VMT factor can also be used to quantify unusual changes in growth patterns.

Distance changes influence the location factors instead of the emission rates themselves. Therefore, a strategy which changes only distance from source to receptor (such as removing all cars from the central business district) will affect only the Modified Roll-back results. In general, moving a source away from the receptor will decrease the pollutant concentration an amount depending on the percentage emissions contributed by that source and the atmospheric stability class. Experience has indicated that the Modified Roll-back model will yield lower estimates of pollutant concentrations then the simple method when the following conditions exist: 1) Mobile sources located closer then stationary, 2) Mobile sources constitute a large component of the total, and 3) Measures applied to mobile sources resulting significant reduction.

Combination strategies can be considered by the model by combining the percentages of separate measures. In general, the analysis of measure interactions is made by the user and the total percentage emission reductions are inputted into the model.

APPENDIX H

GAS RATIONING DURING WORLD WAR II

Chronology

April 1941	The Office of Price Administration (OPA) is formed under the War Production Board to curtail inflation and administer the distribution of essential goods which had become scarce due to the war.
March 1942	Trial gas rationing on East Coast begins. It's due to regional shortage caused by Nazi U-boars sinking American tankers in the Atlantic.
July 1, 1942	Official East Coast gas rationing begins.
December 1, 1942	Official gas rationing extended to all states. However, reason is to conserve the rubber consumption by limiting tire wear. The Japanese had captured 90% of the rubber exporting countries.
December 1943	By this time, gas rationing throughout the United States was based on scarcity of gasoline. Tire wear became a secondary concern.
September 1945	With the end of the war with Japan, gasoline rationing ended.

Administration

Like all of the rationing systems during World War II, the rationing of gasoline was controlled by a system of coupon books. There were two types of ration books: highway types, intended for automobiles, motorcycles, etc., and non-highway types for motorboats, farm machinery, enginers, etc.

Five classes of ration books existed for the highway types. Book "A" was the basic rationing book for passenger cars, as Book "B" was the basic rationing book for motorcycles. If a registered car owner could substantially illustrate that he regularly carried three or more persons in connection with his occupation, or that his ride-sharing plan was infeasible but that alternative transportation was inadequate, he could obtain supplementary rations according to his need. These would be supplied by Book "B". Ration Book "C," affording mileage greater than that of "B," was for passenger automobile drivers whose driving needs were considered most essential to the war effort. Finally, there were two books ("T-1" and "T-2") for certain commercial operations considered essential to the maintenance of the domestic economy (e.g., trucks, buses, taxis, ambulances, military vehicles, etc.). (OPA Plan for Mileage Rationing Instructions to administrators, November, 1942.)

Each coupon was worth a certain amount of gasoline which varied between 2 and 5 gallons throughout the war. Every quarter the Director of Petroleum decided the value of the coupons, usually allowing from 380 to 470 miles of travel per month. Book "A" contained four pages of seven coupons per page. Coupons on each page were numbered successively. Each page was valid for a certain period of time (two or three months) and thereafter became invalid. If a person hadn't used up his coupons for a specified period, he could never use them.

Ration Book "B" (supplement to "A") had 16 coupons intended for three months' use. If the mileage need of the holder was less, the period of use was extended. Book "C" contained 64 coupons, good for a period of three months, "T-1" contained 96 coupons and "T-2" contained 384 coupons worth five gallons each. The "D" coupon books contained 32 coupons, but the value of each coupon was less than that for autos.

The Director of OPA was responsible for nationwide distribution of gasoline ration books. Actual distribution was done by Registrars and

Local War Price and Rationing Board. REgistrars were only responsible for issuing basic ration books for cars and motorcycles ("B" and "D"). All exceptions were handled by the Local War Rationing Boards.

In order to obtain a basic gas rationing book, two forms had to be filled out -- one for the coupon book and one for checking tire wear. Another form, OPA R-535, had to be filled out if the applicant desired supplemental rations. The coupons were issued upon receipt of a complete form with the applicant's signature and a valid motor vehicle registration with the applicant's name on it. In order to obtain supplemental rations, individuals had to somehow show their need. This "proof" was was not standardized, and was quite often based on the honor system.

Basic ration books were distributed initially throughout the U. S. during three days (November 9, 10, and 11, 1942). Other ration books were distributed for the rest of the month by the Local War Price and Rationing Boards.

Records of the number of each coupons issued was kept by the Registrars and Boards. These "Inventory Record Forms" were then sent to the State Director of the OPA. He, in turn, sent a summary report to the OPA.

These records were compiled for comparison to the number of coupons actually used, and the amount of gasoline distributed. The coupons were passed from the car owner to the dealer to the intermediate distributor to the licensed distributor. The licensed distributor was not required to exchange such coupons to secure replenishment of their supplies. Instead they transmitted all of the coupons they received from the intermediate distributors and dealers along with their State tax form.

Another check on the rationing system was accomplished by requiring gasoline dealers and intermediate distributors to register pertinent information with their War Price and Rationing Boards. They indicated on appropriate forms the capacity of their storage tanks and the amount of gasoline at hand at the time of registration.

As the war progressed, the administration and issuance was somewhat simplified. First, the application and renewal forms were shortened and simplified. Then, provisions were made for renewal and other board transactions by mail, thus saving time and travel. Also, the ration banking system was applied to gasoline rationing (OPA, Fourth Report of the Office of Price Administration).

Effectiveness of Program in Reducing Car Mileage

By January 1, 1943, 25 million passenger cars were having their gas intake rationed. Of these autos, 25.4% (6,370,000) were on "B" rations, and 14.3% (3,590,000) were on "C" rations. Thus, over half of the civilians were on "A" rations, or the most limited category. The Office of Price Administration estimated the average mileage per car to have been 5,150 miles, which was one-half of the pre-rationing average mileage. The sale of gas dropped 40% from December 1, 1942 to January 1, 1943 in states west of the Alleghenies. (OPA, Fourth Report of the Office of Price Administration.)

During 1943, daily nationwide driving was reduced by 255 million miles or 32.6% from total mileage in 1941. On a local level the average mileage reduction was 26%.

Public Reaction to Gas Rationing

Overall the public saw gas rationing as a necessary burden borne for the war effort. President Roosevelt's message on an OPA explanatory pamphlet in August 1942 read as follows:

> "We are now in this war. We are all in it -- all the way. Every single man, woman and child is a partner in the most tremendous undertaking of our American history. Ahead there lies sacrifice for all of us.
>
> But it is not correct to use that word. The United States does not consider it a sacrifice to do all one can, to give one's best to our nation, when the nation is fighting for its existence and its future life."

However, when extension of gasoline rationing from the East Coast to the West was considered in Congress "it was greeted with considerable misgiving and opposition in the areas affected." (OPA, Fourth Report of the Office of Price Administration) "Californians feared rationing would mean a traffic holocust especially in spread-out Los Angeles; they freely used words like "panic, riot" to describe their fears of what rationing might bring." (Time, December 30, 1942)

On a more individual basis, people were confused and bitter because the distribution didn't seem fair. "Many who accepted the "A" cards because they did not have to use their cars for business were bitter when they found that some of their neighbors, who could equally well switch to other forms of transportation, had asked for and received "B" or even "X" cards." (The Nation, March 23, 1942)

Problems with Administration and Enforcement

A lot of the administrative problems were ironed out during 1943. But before this time, there were two main problems with administration. First, standards weren't specific enough to actually carry out the fair division of supplies. Proof of need was not required; gasoline rationing was basically on the honor system. Also, procedures for obtaining ration books were time-consuming, confusing and impersonal.

Enforcement problems stemmed from an incomplete system of enforcing proper use of coupons. Each car had a window sticker indicating the type of ration book available to the owner. However, if the owner had obtained extra coupons through the black market these were accepted at many service stations. After five months of rationing on the East Coast, OPA investigators found that 70% of the 500 gas stations in these states were violating gas rationing rules, and distributing more gasoline than they should have. Besides misuse of valid coupons, there was quite a problem to halt distribution of counterfeit coupons. (OPA, First Quarterly Report)